RECEIVED BY TIC MAR 1 1973

(987)

Vegetational Studies on the ALE Reserve, 1972

W. H. Rickard, R. O. Gilbert and J. F. Cline

Ecosystems Department
Battelle Memorial Institute
Pacific Northwest Laboratories
Richland, Washington 99352

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

fey

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Acknowledgements

This work was performed under United States Atomic Energy Commission Contract AT(45-1)-1830 and the Grassland Biome Ecosystems Analysis Studies, U. S. International Biological Program.

Table of Contents

	<u>Page</u>
Abstract	1
Introduction	2
Results	3
Perennial grasses	3
Perennial forbs	4
Half-shrubs	4
Winter annuals	4
Shrubs	4
Standing dead perennial grass	5
Grass crowns	6
Sagebrush wood	6
Belowground biomass	6
Sagebrush Sampling Design and Results	7
Abiotic Measurements	11
Soil properties	11
Soil moisture	11
Air temperature	11
Precipitation	12
Discussion	12
Appendix	37

Abstract

The 1972 annual report for the ALE site emphasizes the impact of cattle grazing as a stress on shrub steppe vegetation that has had a long history of no grazing. After the second consecutive year of spring grazing cattle had reduced the amount of standing dead material of the perennial bunchgrasses and had removed about 70 percent of the net production for the 1972 season. Two plants were highly palatable to cattle, Poa cusickii and Crepis atrabarba. These plants are expected to become greatly reduced in abundance with continued spring grazing.

Sagebrush comprises an unpalatable part of the vegetation as far as cattle forage is concerned but provides about 110 g/m^2 of aboveground biomass in the form of livewood, standing dead wood, leaves and inflorescences.

INTRODUCTION

The annual report for 1972 considers the impact of cattle grazing on a stand of shrub-steppe vegetation that has had a long history of freedom from grazing. Cattle were introduced for the first time to replicate 9 hectare pastures during April and May of 1971 when 15 head of yearling steers were grazed for 58 consecutive days with a weekly change of pastures. The same stocking density was maintained for 1972 but the number of grazing days was reduced to 41.

At the end of the grazing period in 1972 there were visible differences in the vegetation of grazed and ungrazed pastures. Agropyron spicatum was the dominant cattle forage species. Much of the 1972 growth of A. spicatum was removed by grazing and the standing dead grass was also reduced in abundance. Although cattle were removed before the onset of flowering of A. spicatum, only a few seeds were formed by the plants in the grazed pastures as compared to the ungrazed pastures. Poa cusickii, was particularly sought out by cattle and all the bunches available to cattle were grazed down to crown level. Some of the perennial forbs were also eaten. Crepis atrabarba, a perennial forb was especially sought out. The half-shrubs were not grazed by cattle but were damaged by trampling. Sagebrush was not eaten by cattle but some plants were damaged by trampling and some of the taller plants were damaged when cattle used them as rubbing posts. Alien winter annuals, i.e. cheatgrass, characteristic of overgrazed pastures and disturbed soil throughout the shrub steppe region of Washington contributed less than one percent of the total aboveground live biomass on grazed and ungrazed pastures.

The trampling by cattle resulted in the breaking up of the thin soil crust formed by lichens and algae.

RESULTS

Perennial Grasses

Four species of perennial grasses were harvested. Poa secunda, the smallest bunchgrass, was ubiquitous and occurred in every sample taken. However, the plant grows so close to the ground that it probably does not contribute significantly to cattle forage. The flowering stalks range from 1-2 dm in height and these can be grazed. Agropyron spicatum was the dominant grass and the most important for cattle forage. Occasionally this species did not occur in the .5 m² circular plot used for harvesting. Although cattle were removed from the pasture before the onset of flowering of A. spicatum, most of the plants did not produce seeds in the grazed pastures in contrast to the ungrazed pasture on which most of the plants produced at least a few seeds.

Poa cusickii was the most palatable grass and the earliest to flower. Only the clumps protected by sagebrush escaped grazing. Unprotected clumps were grazed to crown level. It seems unlikely that Poa cusickii will survive another year under the spring grazing treatment administered during this experiment unless protected by shrub canopies.

Stipa thurberiana occurred on the pastures but contributed only a small portion of the aboveground biomass.

The perennial grasses tripled in live aboveground biomass between March 6 and March 27 with the ungrazed pastures averaging slightly more growth than the grazed pastures. With the introduction of cattle the live aboveground biomass declined on the grazed pastures. On May 30 only 15 g/m² remained on the grazed pastures as compared to 47 g/m² on the ungrazed pastures (see tables 1-5). From these data it was estimated that about 32 g/m² of live grass was removed by the grazing treatment.

Perennial Forbs

It was clear that the forb most preferred by cattle was Crepis atrabarba. All unprotected plants in the grazed pastures were grazed to ground level. Lupinus laxiflorus was also grazed by cattle but other perennial forbs were not utilized.

Half Shrubs

Three species occurred on the pastures that had aboveground parts that were more than one year old. These are Antennaria dimorpha, Phlox longifolia and Erigeron filifolius. These were plants not grazed by cattle (see tables 1-5).

Winter Annuals

Several species of winter annuals occurred on the pastures but always in amounts too low to be of value as cattle forage (see tables 1-5).

Shrubs

Only one shrub species occurred on the pastures, Artemisia tridentata. Because of its relatively large size and importance in terms of aboveground biomass A. tridentata was sampled separately from other species (see tables A1 and A2).

During the 1971 season, sagebrush shrubs were harvested from 24 randomly located circular plots 2 m^2 in size in both grazed and ungrazed treatments. (The statistical design and analysis procedure is described in the 1971 report to IBP entitled "Vegetational Studies on the ALE Reserve, 1971" by W. H. Rickard, R. O. Gilbert and J. F. Cline). The resulting weight estimates were not suitable due to their large variability resulting from the irregular spacing and relatively large size of the individual shrubs. In an attempt to obtain better estimates of the mean biomass per square meter during the 1972 season a double sampling technique was employed.

Table A1 contains estimates of mean biomass per bush which are data necessary for estimating the quantity of interest namely the biomass per square meter as given in Table A2. The relationship between the data in Table A1 and A2 is given in the next section.

Please note that during the 1972 harvest season shrubs were also harvested as part of the sampling program used for herbaceous species, and are reported for completeness rather than for their information content.

Standing dead perennial grass

Although cattle tend to select the green material from the grass clumps they also eat some of the standing dead grass produced in past years. Because the grazed pastures had been grazed in 1971 there was not as much standing material on the pasture in 1972 as compared to the ungrazed pasture. The harvest results are presented in Tables 7-12 and are briefly summarized below.

Sample Date	Treatment	
	Grazed	Ungrazed
March 6	59 $\pm$ 6	77 $\pm$ 12
March 27	41 $\pm$ 6	76 $\pm$ 15
April 17	47 $\pm$ 5	60 $\pm$ 12
May 8	42 $\pm$ 6	48 $\pm$ 9
May 30	23 $\pm$ 3	72 $\pm$ 9
June 22	18 $\pm$ 6	42 $\pm$ 9
Average	38	62

At the end of the growing season there was less standing dead material in the grazed pastures than on the ungrazed pastures.

Grass crowns

All the perennial bunchgrasses have discrete crowns which can be separated from roots by using a fine-toothed flexible saw blade (hack saw blade). Because of the high degree of soil contamination the cut crowns are washed and floated in water to remove associated soil. The dry weights listed for crowns in Table 13 are from washed material.

Because the pastures have had closely similar past histories it is expected that the short grazing history associated with the grazed pastures would not be reflected in changes in crown weights. On the average 160 g/m^2 of crowns were harvested on the grazed pastures as compared to 151 g/m^2 on the ungrazed pastures.

Sagebrush wood

Because the pastures have supported sagebrush plants for a long time and there has not been a recent fire, wood derived from twigs and stems is present in variable quantities. It is not expected that the short grazing history of the grazed pastures would have affected the quantity of dead wood. On the average the grazed pastures yielded 65 g/m^2 of dead wood as compared to 55 g/m^2 on the ungrazed pasture (Table 14).

Belowground biomass

Belowground biomass was harvested three times during the spring growing season in early March, mid-April and early June. One decimeter depths were taken to a depth of 8 dm using a sharp sand auger. The size of the core was 86 mm in diameter. Forty-eight holes were bored in March and June but only 24 holes were bored in April. A summary of results is presented in Table 15. The data indicate that maximum belowground biomass occurred in April in the grazed pastures while maximum biomass occurred in June in the ungrazed pastures. The data for replicate Number 2 in the ungrazed pastures is not yet complete. A statistical analysis of the data is also pending.

SAGEBRUSH SAMPLING DESIGN AND RESULTS

The basic sampling procedure employed was to use "double sampling" or "two-phase" sampling (W. G. Cochran, Sampling Techniques, second edition, John Wiley & Sons, 1963, pp. 334-339) in conjunction with regression estimation. Data collected in 1969 showed a high correlation between the volume of a sagebrush plant (volume = (largest diameter) x (smallest diameter) x (height)) and the dry weight of the shrub. We made use of this correlation by obtaining a sample of size n bushes. Two attributes of each bush were measured: (1) its volume determined by measuring in the field, and (2) its dry weight as determined in the laboratory. These n pairs of data points were used to estimate a linear calibration equation relating these two variables. Then a sample of size n' shrubs was chosen at random ($n' > n$) for which only volume measurements were obtained; i.e., they were not harvested. With the information from these two samples of size n and n' , an estimate of $\bar{Y}_{ds}$ = mean biomass per bush and its standard error can be obtained using formulae given by Cochran (p. 334 and p. 339) (ds stands for double sampling). The estimate $\bar{Y}_{ds}$ is then multiplied by an estimate of the mean number of bushes per square meter ($\bar{X}$) to obtain the final estimate desired, the mean biomass per square meter, $\bar{Y}$. That is

$$\bar{Y} = \bar{Y}_{ds} \bar{X} \quad (1)$$

The standard error of $\bar{Y}$ was approximated using the so-called Delta method (Taylor series expansion) and by assuming that $\bar{Y}_{ds}$ and $\bar{X}$ are uncorrelated.

Although this latter assumption is probably wishful thinking, it is necessitated by a lack of any knowledge as to what the correlation is. We attempted to estimate this correlation using the data obtained during the course of the above described sampling plan, but the data proved to be too variable to be of any use for this purpose. Hence, the standard error of $\bar{Y}$ was approximated as

$$\begin{aligned} [\text{Var}(\bar{Y})]^{1/2} &= [\text{Var}(\bar{Y}_{ds} \cdot \bar{X})]^{1/2} \\ &\approx [\bar{X}^2 \text{Var}(\bar{Y}_{ds}) + \bar{Y}_{ds}^2 \text{Var}(\bar{X})]^{1/2} \quad (2) \end{aligned}$$

If we had a good estimate of $\text{Cov}(\bar{Y}_{ds}, \bar{X})$ then the term $2\bar{Y}_{ds} \bar{X} \text{Cov}(\bar{Y}_{ds}, \bar{X})$ would be added to the two terms inside the braces in the above formula.

The above procedure was followed for both grazed and ungrazed treatments. An estimate of $\bar{X}$ (the mean number of bushes per square meter) was obtained for both treatments separately, denoted by $\bar{X}_g$ and $\bar{X}_{ug}$ (g = grazed, ug = ungrazed). Similarly $\bar{Y}_{ds}$ was obtained for both treatments and are denoted by $\bar{Y}_{ds,g}$ and $\bar{Y}_{ds,ug}$ (Table A1). The results given in Table A2 do not warrant the conclusion that the biomass of sagebrush on a square meter basis is statistically different in the two treatments. This is not unreasonable in light of our feeling that cattle do not find sagebrush very palatable. Hence, we have also obtained a combined estimate over the two treatments of $\bar{X}$, $\bar{Y}_{ds}$ and $\bar{Y}$. The estimates obtained are thus:

<u>Grazed</u>	<u>Ungrazed</u>	<u>Combined</u>
$\bar{Y}_{ds,g}$	$\bar{Y}_{ds,ug}$	$\bar{Y}_{ds,c}$
$\bar{X}_g$	$\bar{X}_{ug}$	$\bar{X}_c$
$\bar{Y}_g = \bar{Y}_{ds,g} \bar{X}_g$	$\bar{Y}_{ug} = \bar{Y}_{ds,ug} \bar{X}_{ug}$	$\bar{Y}_c = \bar{Y}_{ds,c} \bar{X}_c$

where the standard errors of $\bar{Y}_g$, $\bar{Y}_{ug}$ and $\bar{Y}_c$ were approximated using formula (2) above.

The sample sizes n and n' used in estimating $\bar{Y}_{ds}$ and its standard error for grazed, ungrazed and combined are:

	<u>Grazed</u>	<u>Ungrazed</u>	<u>Combined</u>
n	64	96	160
n'	281	187	468

These samples of bushes were obtained by choosing 3 plots of size 5 x 15 m in each of the 6 strata in each treatment (see "Vegetational Studies on the ALE Reserve, 1971" for a diagram of the field layout with strata). One of the three plots within each strata was chosen at random, and all bushes within these chosen plots (n) were both measured for volume and harvested to be dried and weighed in the laboratory. There was a total of $n = 64$ bushes in these plots for the grazed treatment and $n = 96$ in the ungrazed treatment as indicated above. The bushes in the remaining two 5 x 15 m plots in each strata were not harvested, but their volume measurements were obtained. The total number of these bushes (n') was 281 and 187 in the grazed and ungrazed treatments, respectively.

The biomass of each harvested sagebrush plant was separated in the laboratory into leaves, flowers, livewood, deadwood and miscellaneous, and separate biomass estimates obtained for each category (see Tables A1 and A2). Sagebrush estimates were obtained twice during 1972. Once in June and again in October when the sagebrush was in bloom. For the June harvest we have data only on the biomass of the leaves obtained by harvesting all bushes present in 6 plots of size 5 x 15 m (cluster sampling) for each treatment. Volume measurements were not obtained on these bushes; hence, the double sampling scheme outlined above was used only on the October data. The mean $\pm$ SE biomass of leaves per square meter obtained from the June sampling was 10.66 ± 2.5 and 6.20 ± 1.1 for the grazed and ungrazed treatments, respectively. These compare with 7.17 ± 1.48 and 5.85 ± 0.60 obtained in October (see Table A2).

ABIOTIC MEASUREMENTS

Soil properties

A textural analysis of the soil profiles in grazed and ungrazed pastures is shown in Table 16. There were no strong differences in soil texture among the four pastures. Silt sized particles ranged between 55 and 63 percent of the total composition as compared to a range of between 31 and 40 for sand and 3.3 to 6.9 for clay.

Soil pH values increased with depth. The upper decimeter of soil profile had pH values in the range 6.7 to 7.2 and lower portions of the soil profile had values in the range of 8.2 to 8.3 (Table 17). Other chemical properties of the soil profile are listed in Table 17 and generally show little difference between the various pastures.

Soil moisture

Soil water content of the upper meter of soil profile at various times of the year from October 1971 to July 1972 are shown in Table 18. Soil water content increased in fall and winter months and declined in the spring coincident with the spring flush of plant growth. As in 1971 soil water penetrated shallowly to about 6 dm. Below this depth soil water remained relatively constant indicating no recharge or removal of soil water.

Air temperatures

The daily maximum and minimum air temperatures taken from hygrothermograph strip chart records are shown in the appendix. Also the daily maximum and minimum soil temperatures taken from strip charts on soil thermographs with sensors placed at a one decimeter depth are presented in the appendix.

Precipitation

Weekly precipitation values measured in inches for the period October 1971 to September 1972 are presented in the appendix.

DISCUSSION

The ALE site located in the shrub steppe region of south central Washington differs from other sites in the comprehensive network floristically and also by having the dominant grasses arranged in widely spaced, discrete clumps. Superimposed over the bunchgrasses are small statured and widely spaced plants of the long-lived evergreen shrub Artemisia tridentata. The land use history of the ALE site is unique because of a long period of no grazing under the management of the United States Atomic Energy Commission. The introduction of cattle to the ALE pastures represents a stress to a stand of vegetation that probably has had little previous cattle grazing. The pastures have also not sustained a fire for more than 30 years although adjacent areas have burned as recently as 1957.

The sampling at the ALE site is conducted concurrently with cattle grazing in contrast to other sites where grazing is not conducted during the season of sampling. It is anticipated that in 1973 one previously grazed pasture (1971 and 1972) will not be grazed. Another pasture will be grazed for the third consecutive year and the third pasture will be one that has not been grazed at all. By sampling concurrently with cattle grazing an estimate of forage use can also be obtained for that particular pasture.

Although sagebrush is not a palatable forage for cattle, the plant is a prominent part of the vegetation. It was clearly demonstrated that the kind of sampling used for herbaceous plants would not be useful as a measure of the annual net production of sagebrush. The sampling method used in 1972 provides a more accurate assessment of annual production although it makes no

allowance for growth in stem diameter nor does it fully account for leaves and other persistent tissues that may have been produced at a time prior to the current sample year. However, it is believed that the error introduced here is small as compared to the decisions made in separating live and dead wood. Sagebrush plays a role in protecting grasses beneath its canopy from cattle grazing. Also sagebrush probably competes with herbaceous plants for water and scarce nutrient elements.

The interpretation of results obtained for belowground biomass harvests is difficult because of inherent difficulties in distinguishing and separating new growth roots from those produced in previous seasons.

The climatic regime of the ALE site differs from other network sites located eastward of Rocky Mountains by having winter precipitation followed by a prolonged summer drought. Soil water is replenished during fall and winter months, then steadily declines in spring. Soil water penetration has been shallow during both years of study ie, about 6 dm. However, roots are found in the soil profile below the soil water penetration depth, suggesting that in other years that there is deeper percolation of precipitation.

As a general rule plants with the shallowest root systems flower early in the spring and those with deeper roots flower later. This may be a response to soil drought since the soil profile ordinarily dries from the surface downward. Sagebrush has an unusual phenology since it flowers in the autumn after enduring several months of soil drought and extreme summer temperatures.

A unique feature of this grassland is the possibility of winter growth (also characteristic of California annual grassland). Growth starts in fall with the first soaking rain and may continue in short periods of above freezing temperatures. As spring temperatures rise, soil water reserves are depleted and the growth cycle is complete. Thus, the growing season is confined to a short

period during which adequate soil water and moderate temperatures occur simultaneously.

The ALE version of the ELM model uses field data collected in 1971 and 1972. Applying ELM to shrub steppe vegetation has pointed out several weaknesses in the model. The data have been used to develop modelling representations of topics not addressed in the Pawnee version of ELM. For example, the role of crown material in grasses (and perhaps live wood in shrubs as well) appears to be overwinter storage and as such this biomass category has been removed from the root categories which now serve as absorptive structures only. Thus, the effect of cattle grazing on the crowns and the relative vigor of the important species can be simulated by observing the material stored in the crowns. Another example: The ability to address the biomass and phenological dynamics of annual species, absent in the Pawnee version of ALM, has been added to the ALE version to account for Bromus tectorum, a vigorous annual grass. Also, the fall flowering time of sagebrush, initiated an extensive revision of the phenological dynamics section of the model, and this section now produces good relationships between plant development and climatic variability and change. In summary, the ELM model is much improved for its application to the phenological and biomass dynamics of the rather unique vegetation of the ALE reserve. The resulting changes in ELM are expected to improve ELM's applicability to other sites in the grassland biome.

Table 1. Live aboveground biomass (g/m^2) in grazed and ungrazed pastures on the ALE site, South Central Washington, March 6, 1972.

	<u>Grazed</u>	<u>Ungrazed</u>
<u>Perennial Grasses</u>		
Agropyron spicatum	1.7 $\pm$.3	2.1 $\pm$.5
Poa cusickii	.3 $\pm$.2	.3 $\pm$.2
Poa secunda	3.0 $\pm$.3	3.6 $\pm$.2
Stipa thurberiana	.04 $\pm$.03	.04 $\pm$.04
Total	4.7 $\pm$.4	6.1 $\pm$.4
<u>Half Shrubs</u>		
Antennaria dimorpha	.5 $\pm$.5	1.0 $\pm$.5
Erigeron filifolius	.7 $\pm$.3	1.3 $\pm$.7
Phlox longifolia		.3 $\pm$.2
Total	1.2 $\pm$.5	1.6 $\pm$.6
<u>Perennial Forbs</u>		
Astragalus purshii		.05 $\pm$.05
Brodiaea douglasii	.002 $\pm$.001	
Calachortus macrocarpus		.04 $\pm$.02
Lomatium macrocarpus	.04 $\pm$.01	.06 $\pm$.01
Total	.04 $\pm$.01	1.2 $\pm$.5
<u>Winter Annuals</u>		
(Not harvestable)		
<u>Shrubs</u>		
Artemisia tridentata		
Leaves	2.8 $\pm$ 1.6	1.4 $\pm$ 1.2
Wood	31.7 $\pm$ 20.3	20.4 $\pm$ 14.5

Table 2. Live aboveground biomass (g/m^2) in grazed and ungrazed pastures on the ALE site, South Central Washington, March 27, 1972.

	Grazed	Ungrazed
<u>Perennial Grasses</u>		
Agropyron spicatum	7.6 $\pm$ 1.2	11.5 $\pm$ 1.8
Poa cusickii	1.1 $\pm$.7	3.0 $\pm$ 1.2
Poa secunda	5.6 $\pm$.6	6.4 $\pm$.5
Stipa thurberiana	.7 $\pm$.4	.08 $\pm$.07
Total	15.0 $\pm$ 1.5	21.0 $\pm$ 2.0
<u>Half Shrubs</u>		
Antennaria dimorpha	1.9 $\pm$.9	.7 $\pm$.4
Erigeron filifolius	.6 $\pm$.3	1.2 $\pm$.3
Phlox longifolia	.3 $\pm$.2	1.0 $\pm$.4
Total	2.8 $\pm$.8	2.9 $\pm$.5
<u>Perennial Forbs</u>		
Astragalus purshii		.014 $\pm$.014
Calochortus macrocarpus	.09 $\pm$.05	.06 $\pm$.03
Crepis atrabarba	1.2 $\pm$.4	.17 $\pm$.11
Lomatium macrocarpus	.11 $\pm$.03	.19 $\pm$.06
Lupinus laxiflorus	.02 $\pm$.02	.11 $\pm$.08
Achillea lanulosa	.003 $\pm$.003	
Unidentified	.01 $\pm$.01	.007 $\pm$.006
Total	1.6 $\pm$.4	.55 $\pm$.16
<u>Winter Annuals</u>		
Descurainia pinnata	.019 $\pm$.004	.002 $\pm$.001
Draba verna	.006 $\pm$.002	.06 $\pm$.03
Festuca octoflora	.011 $\pm$.002	.004 $\pm$.001
Bromus tectorum	.002 $\pm$.001	
Sisymbrium altissimum	.001 $\pm$.001	
Total	.038 $\pm$.003	.062 $\pm$.033
<u>Shrubs</u>		
Artemisia tridentata		
Leaves	1.2 $\pm$.9	1.0 $\pm$.79
Wood	36.6 $\pm$ 26.7	3.8 $\pm$ 2.4
Total	37.8 $\pm$ 27.5	4.8 $\pm$ 3.1

Table 3. Live aboveground biomass (g/m^2) in grazed and ungrazed pastures on the ALE site, South Central Washington, April 17, 1972.

	<u>Grazed</u>			<u>Ungrazed</u>		
<u>Perennial Grasses</u>						
Agropyron spicatum	21.0	+	2.1	19.1	+	2.7
Poa cusickii	.6	+	.2	1.7	+	1.0
Poa secunda	3.6	+	.5	5.2	+	.3
Stipa thurberiana	.5	+	.3			
Total	25.8	+	.9	26.0	+	2.9
<u>Half Shrubs</u>						
Antennaria dimorpha	1.2	+	.9	2.2	+	1.5
Erigeron filifolius	.7	+	.3	1.4	+	.5
Phlox longifolia	.01	+	.01	.6	+	.2
Total	1.9	+	1.0	4.2	+	1.6
<u>Perennial Forbs</u>						
Astragalus purshii				.09	+	.04
Calochortus macrocarpus	.09	+	.05	.03	+	.02
Crepis atrabarba	.9	+	.3	.2	+	.1
Lomatium macrocarpus	.4	+	.3	.2	+	.05
Lupinus laxiflorus	.3	+	.3	.3	+	.2
Total	1.7	+	.5	.8	+	.3
<u>Winter Annuals</u>						
Descurainia pinnata	.06	+	.02	.001	+	.001
Draba verna	.001	+	.001			
Festuca octoflora	.5	+	.2	.17	+	.05
Bromus tectorum	.002	+	.001	.002	+	.001
Total	.6	+	.2	.2	+	.05
<u>Shrubs</u>						
Artemisia tridentata						
Leaves	7.6	+	5.7	27.7	+	21.1
Wood	1.3	+	.8	12.0	+	9.5
Total	8.9	+	6.1	39.7	+	27.8

Table 4. Live aboveground biomass (g/m^2) in grazed and ungrazed pastures on the ALE site, South Central Washington, May 8, 1972.

	<u>Grazed</u>			<u>Ungrazed</u>		
<u>Perennial Grasses</u>						
Agropyron spicatum	18.6	+	2.6	25.7	+	6.3
Poa cusickii	.2	+	.1	.8	+	.7
Poa secunda	dead			.08	+	.08
Stipa thurberiana	.1	+	.1	1.0	+	.7
Total	18.9	±	2.6	28.3	±	5.6
<u>Half Shrubs</u>						
Antennaria dimorpha	3.5	+	1.9	1.2	+	1.0
Erigeron filifolius	.9	+	.4	4.3	+	2.3
Phlox longifolia	.05	+	.04	2.2	+	.9
Total	4.5	±	2.3	8.4	±	2.4
<u>Perennial Forbs</u>						
Astragalus purshii				2.6	+	2.0
Calochortus macrocarpus	.2	+	.1	.11	+	.04
Crepis atrabarba	.4	+	.2	1.4	+	.8
Lomatium macrocarpum	.07	+	.02	.18	+	.08
Lupinus laxiflorus	.01	+	.01	.9	+	.6
Total	.66	±	.22	5.1	±	1.8
<u>Winter Annuals</u>						
Descurainaea pinnata	.11	+	.09	.001	+	.001
Festuca octoflora	1.1	+	.4	1.1	+	.2
Bromus tectorum	.01	+	.01	.008	+	.008
Plantago purshii	.2	+	.2			
Total	1.4	±	.45	1.1	±	.2
<u>Shrubs</u>						
Artemisia tridentata						
Leaves	5.1	+	4.3	11.2	+	6.5
Wood	26.4	±	24.9	44.1	±	29.3
Total	31.5	±	25.0	55.3	±	35.5

Table 5. Live aboveground biomass (g/m^2) in grazed and ungrazed pastures on the ALE site, South Central Washington, May 30, 1972.

	<u>Grazed</u>			<u>Ungrazed</u>		
<u>Perennial Grasses</u>						
Agropyron spicatum	14.0	+	2.5	44.1	+	7.2
Poa cusickii	.07	+	.06	1.7	+	1.5
Poa secunda	.18	+	.08	1.0	+	.3
Stipa thurberiana	.3	+	.2	.5	+	.5
Total	14.6	+	2.4	47.2	+	6.4
<u>Half Shrubs</u>						
Antennaria dimorpha	3.2	+	2.0	10.6	+	6.0
Erigeron filifolius	2.6	+	.8	2.7	+	1.8
Phlox longifolia	.02	+	.02	.5	+	.1
Total	5.8	+	2.3	13.3	+	6.3
<u>Perennial Forbs</u>						
Calochortus macrocarpus				.07	+	.04
Astragalus purshii				.3	+	.2
Crepis atrabarba	.5	+	.2	4.1	+	2.3
Lomatium macrocarpus	.002	+	.001	.002	+	.002
Lupinus laxiflorus	.08	+	.07	.1	+	.1
Brodiaea douglasii				.4	+	.4
Total	.6	+	.2	5.0	+	2.4
<u>Winter Annuals</u>						
Descurainia pinnata	.02	+	.008	.003	+	.003
Festuca octoflora	.05	+	.05			
Bromus tectorum	.009	+	.003			
Plantago purshii	.10	+	.07			
Total	.17	+	.12	.003	+	.003
<u>Shrubs</u>						
Artemisia tridentata						
Leaves	.4	+	.4	12.3	+	12.0
Wood	1.2	+	1.2	.6	+	.6
Total	1.6	+	1.6	12.9	+	12.0

Table 6. Live aboveground biomass (g/m^2) in grazed and ungrazed pastures on the ALE site, South Central Washington, June 22, 1972.

	<u>Grazed</u>			<u>Ungrazed</u>		
<u>Perennial Grasses</u>						
Agropyron spicatum	11.3	+	2.6	26.1	+	3.3
Poa cusickii	.5	+	.5	.7	+	.7
Poa secunda						
Stipa thurberiana	.3	+	.2			
Total	12.1	+	2.9	26.7	+	3.5

(Other plants not harvested.)

TABLE A1

SAGEBRUSH BIOMASS IN GRAMS/BUSH (OCTOBER, 1972), ALE SITE

	<u>Grazed</u>	<u>Ungrazed</u>	<u>Combined</u>
Leaves	28.00 $\pm$ 3.04	27.60 $\pm$ 2.68	25.78 $\pm$ 1.99
Livewood	226.16 $\pm$ 19.51	433.07 $\pm$ 46.27	315.65 $\pm$ 25.79
Leaves and Livewood	254.17 $\pm$ 20.92	460.67 $\pm$ 48.13	341.53 $\pm$ 26.84
Flowers	3.45 $\pm$ 1.07	1.30 $\pm$ 0.32	2.00 $\pm$ 0.48
Deadwood	112.55 $\pm$ 12.61	138.22 $\pm$ 30.97	116.79 $\pm$ 18.55
Miscellaneous	14.20 $\pm$ 1.52	21.41 $\pm$ 2.60	16.86 $\pm$ 1.56
Livewood and Deadwood	338.71 $\pm$ 23.97	571.29 $\pm$ 70.89	432.49 $\pm$ 39.32
Flowers and Leaves	31.46 $\pm$ 3.43	28.90 $\pm$ 2.79	27.78 $\pm$ 2.15
Total	384.37 $\pm$ 26.21	621.60 $\pm$ 74.26	477.08 $\pm$ 41.07

Data are $\bar{Y}_{ds} \pm SE$, where $\bar{Y}_{ds}$ = mean biomass per bush obtained using double sampling.

TABLE A2

SAGEBRUSH BIOMASS IN GRAMS/m² (OCTOBER, 1972), ALE SITE[†]

	<u>Grazed</u>	<u>Ungrazed*</u>	<u>Combined</u>
Leaves	7.17 $\pm$ 1.48	5.85 $\pm$ 0.60	6.03 $\pm$ 0.84
Livewood	57.90 $\pm$ 11.34	91.72 $\pm$ 16.63	73.86 $\pm$ 10.49
Leaves and Livewood	65.07 $\pm$ 12.63	97.57 $\pm$ 17.55	79.89 $\pm$ 11.21
Flowers	0.88 $\pm$ 0.31	0.28 $\pm$ 0.08	0.468 $\pm$ 0.12
Deadwood	28.81 $\pm$ 6.01	29.27 $\pm$ 7.84	27.328 $\pm$ 5.38
Miscellaneous	3.63 $\pm$ 0.75	4.53 $\pm$ 0.86	3.945 $\pm$ 0.59
Livewood and Deadwood	86.71 $\pm$ 16.43	121.00 $\pm$ 23.23	101.19 $\pm$ 14.93
Flowers and Leaves	8.05 $\pm$ 1.67	6.12 $\pm$ 1.07	6.50 $\pm$ 0.91
Total	98.40 $\pm$ 18.55	131.65 $\pm$ 24.88	111.64 $\pm$ 16.15

[†]Data are $\bar{Y} \pm \text{S.E.}$, where $\bar{Y}$ = mean biomass per square meter. The estimates $\bar{X}_g, \bar{X}_{ug}$ and $\bar{X}_c$ used to obtain the above results using equations (1) and (2) are $0.256 \pm .045$, $0.212 \pm .031$ and $0.234 \pm .027$, respectively, ($\bar{X} \pm \text{S.E.}$).

*The higher yields in the ungrazed treatment are due in large part to one of the 6 sampling plots of size 5 x 15 meters falling partly over a gully which contained a large number of very old and large sagebrush. The inclusion of these samples results in standard errors of greater magnitude than obtained for the grazed treatment, as well as increasing the spread between the mean yields of the grazed and ungrazed treatments.

Table 7. Standing dead aboveground biomass (g/m^2) in grazed and ungrazed pastures on the ALE project, South Central Washington, March 6, 1972.

	<u>Grazed</u>	<u>Ungrazed</u>
<u>Perennial Grasses</u>		
Agropyron spicatum	49.9 $\pm$ 7	64.6 $\pm$ 11.4
Poa cusickii		1.9 $\pm$ 1.3
Poa secunda	7.6 $\pm$ 1.0	8.2 $\pm$.6
Stipa thurberiana	1.2 $\pm$ 1.0	2.1 $\pm$ 2.1
Total	58.6 $\pm$ 6.2	76.7 $\pm$ 12.1
<u>Half Shrubs</u>		
Antennaria dimorpha		.8 $\pm$.8
Erigeron filifolius	.11 $\pm$.08	.8 $\pm$.5
Phlox longifolia		1.3 $\pm$.7
Total	.11 $\pm$.08	2.0 $\pm$.5
<u>Perennial Forbs</u>		
Lomatium macrocarpus		.06 $\pm$.06
Lupinus laxiflorus		.03 $\pm$.03
Total		.09 $\pm$.06
<u>Shrubs</u>		
Artemisia tridentata	45.2 $\pm$ 18.2	35.9 $\pm$ 25.5

Table 8. Standing dead aboveground biomass (g/m^2) in grazed and ungrazed pastures on the ALE project, South Central Washington, March 27, 1972.

	<u>Grazed</u>	<u>Ungrazed</u>
<u>Perennial Grasses</u>		
Agropyron spicatum	34.4 $\pm$ 7.0	64.5 $\pm$ 15.5
Poa cusickii	.5 $\pm$.3	5.7 $\pm$ 3.2
Poa secunda	3.8 $\pm$.8	5.7 $\pm$.5
Stipa thurberiana	2.7 $\pm$ 1.6	.2 $\pm$.2
Total	41.4 $\pm$ 6.2	76.0 $\pm$ 15.0
<u>Half Shrubs</u>		
Antennaria dimorpha	.60 $\pm$.22	
Erigeron filifolius	.05 $\pm$.05	.09 $\pm$.08
Phlox longifolia		1.5 $\pm$ 1.5
Total	.65 $\pm$.23	1.6 $\pm$ 1.5
<u>Perennial Forbs</u>		
Crepis atrabarba	.9 $\pm$.3	.3 $\pm$.3
Lupinus laxiflorus		.02 $\pm$.02
Total	.9 $\pm$.3	.3 $\pm$.3
<u>Shrubs</u>		
Artemisia tridentata	51.6 $\pm$ 29.6	76.6 $\pm$ 27.4

Table 9. Standing dead aboveground biomass (g/m^2) in grazed and ungrazed pastures on the ALE project, South Central Washington, April 17, 1972.

	<u>Grazed</u>	<u>Ungrazed</u>
<u>Perennial Grasses</u>		
Agropyron spicatum	42.9 $\pm$ 4.7	54.9 $\pm$ 12.4
Poa cusickii	.5 $\pm$.3	1.0 $\pm$.7
Poa secunda	3.1 $\pm$.3	4.4 $\pm$.4
Stipa thurberiana	.8 $\pm$.5	
Total	47.3 $\pm$ 4.8	60.3 $\pm$ 12.5
<u>Half Shrubs</u>		
Antennaria dimorpha	.12 $\pm$.12	.4 $\pm$.4
Erigeron filifolius		.4 $\pm$.3
Phlox longifolia		1.7 $\pm$ 1.2
Total	.12 $\pm$.12	2.5 $\pm$.8
<u>Perennial Forbs</u>		
Crepis atrabarba	.3 $\pm$.2	.6 $\pm$.6
<u>Winter Annuals</u>		
Fectuca octoflora	.3 $\pm$.2	
<u>Shrubs</u>		
Artemisia tridentata	33.0 $\pm$ 14.1	22.2 $\pm$ 17.3

Table 10. Standing dead aboveground biomass (g/m^2) in grazed and ungrazed pastures on the ALE project in South Central Washington, May 8, 1972.

	<u>Grazed</u>	<u>Ungrazed</u>
<u>Perennial Grasses</u>		
Agropyron spicatum	37.7 $\pm$ 6.6	38.3 $\pm$ 9.6
Poa cusickii	.3 $\pm$.2	.9 $\pm$.9
Poa secunda	4.2 $\pm$.7	7.6 $\pm$.6
Stipa thurberiana	.3 $\pm$.2	.7 $\pm$.5
Total	42.5 $\pm$ 6.4	48.3 $\pm$ 8.9
<u>Half Shrubs</u>		
Antennaria dimorpha		.8 $\pm$.8
Erigeron filifolius		.6 $\pm$.6
Total		1.4 $\pm$ 1.0
<u>Perennial Forbs</u>		
Crepis atrabarba	.2 $\pm$.2	1.1 $\pm$.1
<u>Shrubs</u>		
Artemisia tridentata	14.2 $\pm$ 12.0	

Table 11. Standing dead aboveground biomass (g/m^2) in grazed and ungrazed pastures on the ALE project, South Central Washington, May 30, 1972.

	<u>Grazed</u>			<u>Ungrazed</u>		
<u>Perennial Grasses</u>						
Agropyron spicatum	20.5	$\pm$	3.4	63.8	$\pm$	10.5
Poa cusickii	.2	$\pm$	.1	2.4	$\pm$	2.3
Poa secunda	1.7	$\pm$	.3	4.1	$\pm$	.8
Stipa thurberiana	1.1	$\pm$	.7	.7	$\pm$	.7
Total	23.5	$\pm$	3.4	71.7	$\pm$	8.7
<u>Half Shrubs</u>						
Erigeron filifolius	.3	$\pm$	.2	.4	$\pm$	.3
Phlox longifolia				.8	$\pm$	.4
Total	.3	$\pm$	.2	1.2	$\pm$	.5
<u>Perennial Forbs</u>						
Crepis atrabarba	.6	$\pm$	.4	2.4	$\pm$	1.7
<u>Shrubs</u>						
Artemisia tridentata	16.1	$\pm$	16.1	19.7	$\pm$	14.2

Table 12. Standing dead aboveground biomass (g/m^2) in grazed and ungrazed pastures on the ALE project, South Central Washington, June 22, 1972.

	<u>Grazed</u>	<u>Ungrazed</u>
<u>Perennial Grasses</u>		
Agropyron spicatum	17.8 $\pm$ 6.5	41.7 $\pm$ 9.0
Poa cusickii		
Poa secunda		
Stipa thurberiana	.5 $\pm$.4	
Total	18.2 $\pm$ 6.4	41.7 $\pm$ 9.0

(No harvest of half-shrubs, perennial forbs, or shrubs.)

Table 3. Crown* biomass in grazed and ungrazed pastures on the ALE project, South Central Washington, 1972.

	<u>Grazed</u>					Avg.
	March 6	March 27	April 17	May 8	May 30	
<i>Agropyron spicatum</i>	65.7 $\pm$ 10.1	51.1 $\pm$ 11.7	95.7 $\pm$ 11.4	12.8 $\pm$ 16	97.9 $\pm$ 12.1	
<i>Poa cusickii</i>	0 $\pm$ 0	17.7 $\pm$ 10.6	18.2 $\pm$ 14.7	14.4 $\pm$ 8	12.6 $\pm$ 9.4	
<i>Poa secunda</i>	51.2 $\pm$ 7.0	52.3 $\pm$ 8.9	55.7 $\pm$ 5.0	66.1 $\pm$ 9.2	57.3 $\pm$ 11.5	
<i>Stipa thurberiana</i>	.9 $\pm$.8	9.8 $\pm$ 6.7	1.6 $\pm$ 1.1	.5 $\pm$.5	1.4 $\pm$.9	
Total	117.8 $\pm$ 12.4	130.8 $\pm$ 18.2	171.2 $\pm$ 17.7	208.9 $\pm$ 14.1	169.1 $\pm$ 14.7	159.56
	<u>Ungrazed</u>					
	March 6	March 27	April 17	May 8	May 30	
<i>Agropyron spicatum</i>	72.4 $\pm$ 11.4	78.8 $\pm$ 12	59.6 $\pm$ 9.9	64.6 $\pm$ 14.1	114.8 $\pm$ 7.5	
<i>Poa cusickii</i>	7.3 $\pm$ 5.4	24.5 $\pm$ 9.6	8.1 $\pm$ 5.8	8.6 $\pm$ 8.3	13.4 $\pm$ 13.3	
<i>Poa secunda</i>	67.6 $\pm$ 5.4	59.3 $\pm$ 5.1	48.0 $\pm$ 5.2	61.2 $\pm$ 12.0	58.8 $\pm$ 7.4	
<i>Stipa thurberiana</i>	3.8 $\pm$ 3.8	0 $\pm$ 0	0 $\pm$ 0	1.2 $\pm$.9	2.0 $\pm$ 2.0	
Total	151.1 $\pm$ 13.2	162.6 $\pm$ 18.4	115.7 $\pm$ 13.6	135.7 $\pm$ 14.4	189.1 $\pm$ 16.6	150.84

* Values are oven dry weights of washed crowns not corrected for residual soil contamination.

Table 14. Dead wood biomass in grazed and ungrazed pastures on the ALE project, South Central Washington, 1972.

	<u>Grazed</u>	<u>Ungrazed</u>
March 6	51.4 $\pm$ 16.2	67.6 $\pm$ 22.3
March 27	59.3 $\pm$ 19.2	96.6 $\pm$ 24.3
April 17	92.3 $\pm$ 15.3	22.6 $\pm$ 5.9
May 8	49.0 $\pm$ 14.0	47.8 $\pm$ 16.3
May 30	74.1 $\pm$ 30.4	52.3 $\pm$ 15.6
Total	65.2 $\pm$ 9.3	54.7 $\pm$ 9.8
Grazed and ungrazed combined	61.3 $\pm$ 3.4	

Table 15. Belowground biomass in grazed and ungrazed pastures during 1972, ash free weight.

dm	March 6		Grazed Treatment April 17		June 1	
	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2
0-1	1.43 ± .22	1.62 ± .36	2.41 ± .30	3.61 ± .80	2.10 ± .66	3.25 ± .46
1-2	.61 ± .07	1.07 ± .30	1.48 ± .13	2.44 ± .60	.99 ± .11	1.66 ± .18
2-3	.51 ± .04	.69 ± .10	1.07 ± .12	1.20 ± .22	.69 ± .09	1.01 ± .09
3-4	.54 ± .08	.56 ± .04	1.04 ± .11	1.10 ± .25	.69 ± .06	.90 ± .07
4-5	.41 ± .08	.63 ± .09	.97 ± .20	.87 ± .12	.66 ± .03	.74 ± .06
5-6	.51 ± .06	.46 ± .04	.89 ± .07	.86 ± .16	.62 ± .04	.75 ± .07
6-7	.46 ± .06	.37 ± .04	.69 ± .05	.68 ± .10	.56 ± .04	.64 ± .04
7-8	.30 ± .04	.38 ± .04	.58 ± .05	.55 ± .09	.50 ± .07	.52 ± .05
Total	4.80 ± .36	5.78 ± .57	9.12 ± .71	11.34 ± .21	6.82 ± .99	9.49 ± .80
g/m ²	826	994	1569	1950	1173	1632
Ungrazed Treatment						
0-1	1.08 ± .22	1.54 ± .13	1.40 ± .24	1.46 ± .27	2.63 ± .32	M
1-2	.60 ± .06	.64 ± .04	1.11 ± .21	1.21 ± .31	1.48 ± .20	M
2-3	.58 ± .14	.66 ± .10	.67 ± .10	.73 ± .08	.95 ± .08	M
3-4	.49 ± .11	.59 ± .04	.67 ± .11	.69 ± .08	.83 ± .07	M
4-5	.46 ± .05	.52 ± .02	.65 ± .07	.64 ± .06	.65 ± .08	M
5-6	.42 ± .02	.53 ± .03	.58 ± .04	.67 ± .04	.79 ± .08	M
6-7	.38 ± .023	.48 ± .02	.61 ± .06	.55 ± .07	.63 ± .03	M
7-8	.32 ± .034	.39 ± .02	.44 ± .06	.49 ± .07	.56 ± .07	M
Total	4.32 ± .30	5.80 ± .33	6.18 ± .60	6.95 ± .74	8.54 ± .79	M
g/m ²	745	998	1063	1196	1469	M

M = in progress

n = 48 except on April 17 when n=24

Multiply non total values by 172 to convert Zo to g/n²

Table 16. Soil textural analysis in grazed and ungrazed pastures.

Depth (dm)	Grazed treatment (rep. 1)		
	% Sand	% Silt	% Clay
0-1	33.9	60.8	5.3
1-2	32.1	61.6	6.3
2-4	34.7	59.3	6.0
4-6	37.1	57.7	5.2
6-10	38.5	55.7	5.8
Grazed treatment (rep. 2)			
0-1	33.1	60.0	6.9
1-2	32.4	61.3	6.3
2-4	36.0	60.0	4.0
4-6	40.2	56.5	3.3
6-10	39.4	55.5	5.1
Ungrazed treatment (rep. 1)			
0-1	31.1	63.0	5.9
1-2	31.6	61.5	6.9
2-4	35.2	59.8	5.0
4-6	36.3	58.5	5.2
6-10	40.2	55.5	4.3
Ungrazed treatment (rep. 2)			
0-1	39.8	54.0	6.2
1-2	33.9	61.1	5.0
2-4	39.7	60.8	4.5
4-6	36.1	59.7	4.2
6-10	38.0	56.9	4.1

Table 17

Soil Properties in Grazed and Ungrazed Pastures

	Depth -dm	Grazed		Ungrazed	
		Rep 1	Rep 2	Rep 1	Rep 2
pH	0-1	7.2	7.0	6.7	6.8
	1-2	7.0	7.1	7.1	7.0
	2-4	7.5	7.2	7.1	7.3
	4-6	7.9	7.7	7.4	7.8
	6-10	8.2	8.2	8.3	8.3
OM%	0-1	.6	.7	.6	.5
	1-2	.8	.4	.5	.4
	2-4	.4	.5	.6	.4
	4-6	.6	.8	.8	.5
	6-10	.4	.1	.5	.5
P (ppm)	0-1	10	10	14	12
	1-2	11	10	10	8
	2-4	8	2	10	8
	4-6	2	.5	4	2
	6-10	2	.5	2	15
K (ppm)	0-1	230	250	320	270
	1-2	300	220	320	120
	2-4	170	160	200	180
	4-6	100	100	100	110
	6-10	80	80	80	100
Ca meg/100g	0-1	6.0	5.0	4.8	5.3
	1-2	5.2	5.8	5.8	5.8
	2-4	7.0	6.8	6.5	6.5
	4-6	27.6	11.7	8.0	9.3
	6-10	28.8	29.6	30.0	31.0
mg /100g	0-1	3.7	3.2	3.1	3.2
	1-2	3.2	3.9	3.4	3.7
	2-4	3.9	4.1	3.9	3.8
	4-6	4.7	4.5	4.0	4.0
	6-10	4.9	4.8	5.1	5.1

Table 17 (Continued)

(Continued)

	Depth dm	Grazed		Ungrazed	
		Rep 1	Rep 2	Rep 1	Rep 2
N %	0-1	.038	.039	.042	.044
	1-2	.048	.022	.034	.050
	2-4	.039	.022	.040	.048
	4-6	.039	.044	.042	.049
	6-10	.022	.039	.022	.040
Total Bases meg/100g	0-1	10.2	8.8	8.7	9.1
	1-2	9.2	10.2	10.0	9.8
	2-4	11.3	11.3	10.9	10.8
	4-6	32.6	16.5	12.3	13.6
	6-10	34.0	34.7	35.4	36.4

Table 18

Soil Moisture (percent dry wt) in Ungrazed Pastures During
the 1971-72 Growing Season

Depth dm	Oct 27	Nov 4	Nov 24	Dec 2	Jan 17	Feb 17	Mar 1	Mar 24	Apr 3
0-1	3.9	5.2	9.1	13.7	16.9	17.4	10.9	10.1	8.6
1-2	4.0	4.2	5.0	5.4	14.9	16.4	12.3	12.0	10.9
2-3	4.5	4.6	5.8	3.5	11.4	15.3	12.3	12.1	11.3
3-4	4.9	5.2	5.3	5.6	9.0	13.9	11.5	11.5	11.3
4-5	5.2	5.6	5.2	5.8	8.6	11.8	9.4	9.7	10.8
5-6	5.3	5.9	5.3	5.8	7.4	11.7	7.1	8.5	8.2
6-7	5.3	5.7	4.9	5.5	5.7	7.1	5.3	6.5	6.7
7-8	4.8	5.2	4.6	5.4	5.6	5.9	5.3	5.0	5.7
8-9	4.3	4.6	4.2	5.0	4.8	-	4.7	4.5	4.9
9-10	4.0	4.0	4.1	5.1	4.0	-	4.4	4.2	4.3
	Apr 10	Apr 20	Apr 27	May 9	Jun 1	Jun 21	Jun 27	Jul 10	
0-1	7.7	5.7	4.6	11.8	4.4	3.4	6.0	3.2	
1-2	9.9	8.1	8.2	6.5	6.2	4.8	4.9	4.7	
2-3	10.4	9.1	8.9	6.7	6.3	5.5	5.3	5.5	
3-4	10.6	9.4	9.0	6.9	6.7	6.0	5.4	6.0	
4-5	11.1	9.7	9.1	7.4	6.7	5.8	5.5	6.5	
5-6	10.3	9.4	8.8	7.6	6.4	5.8	5.4	6.4	
6-7	8.0	7.7	7.6	6.8	7.2	5.5	5.2	5.3	
7-8	6.2	5.5	6.3	5.9	5.7	5.0	4.6	5.1	
8-9	4.7	4.8	5.6	4.6	4.2	4.4	4.1	4.8	
9-10	4.0	4.5	4.5	4.3	4.1	4.1	3.9	4.0	

Continued

Table 18

Soil Moisture (percent dry wt) in
the Grazed Pastures 1971-72

Depth dm	1971					1972				
	Oct	Nov	Nov	Dec	Jan	Feb	Mar	Mar	Apr	Apr
	27	4	24	2	17	17	1	24	3	10
0-1	3.7	5.4	7.6	14.2	18.8	15.4	11.5	10.3	7.6	7.2
1-2	4.0	4.5	7.2	7.0	15.6	14.8	13.1	15.0	10.5	9.4
2-3	4.5	5.1	5.1	5.7	11.0	14.3	13.3	11.1	11.6	9.6
3-4	5.2	5.6	5.7	6.1	10.0	11.6	13.0	10.3	11.6	10.2
4-5	5.5	5.7	6.0	6.0	8.2	7.9	11.6	10.1	10.0	9.8
5-6	5.2	5.9	6.3	5.9	6.1	6.3	7.9	9.0	6.2	9.3
6-7	4.5	5.0	5.6	5.6	5.4	5.8	5.1	6.5	5.3	7.6
7-8	4.0	4.1	4.6	5.2	4.7	5.6	4.5	5.9	5.0	5.9
8-9	3.7	4.4	4.8	5.0	4.1	-	4.4	5.0	4.4	5.0
9-10	3.6	4.0	4.2	5.1	4.0	-	4.3	4.8	4.3	4.4
	Apr	Apr	May	Jun	Jun	Jun	Jul			
	20	27	9	1	21	27	10			
0-1	5.1	4.2	11.9	5.5	4.8	7.3	3.8			
1-2	7.7	7.8	6.7	7.0	5.3	5.6	5.3			
2-3	9.2	9.1	7.2	6.3	6.1	6.1	5.8			
3-4	10.3	9.2	7.7	7.1	6.4	6.0	6.1			
4-5	10.6	9.9	7.6	7.4	6.0	6.0	6.0			
5-6	8.0	9.1	7.3	7.0	5.8	5.7	5.9			
6-7	5.7	6.8	6.4	5.4	6.0	5.3	5.4			
7-8	5.2	5.6	5.4	4.5	5.4	4.7	4.9			
8-9	5.1	4.8	4.5	4.7	4.9	4.3	6.5			
9-10	4.5	4.8	4.4	4.3	4.5	4.1	4.3			

APPENDIX

Maximum Air Temperatures °C 1971-72 Growing Season, ALE

	1971				1972									
	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec</u>	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sept</u>	<u>Oct</u>
1		19.0	11.0	2.0	9.0		2.0		17.0	10.0	16.5	34.0	29.0	26.5
2		19.0	10.0	3.5	5.5		9.5	10.5	23.0	11.5	28.0	32.0	30.0	24.5
3		24.5	15.0	1.5	-1.0		6.5	13.5	24.0	14.0	30.0	33.0	31.0	24.5
4		26.5	11.5	6.5	1.0		5.5	18.5	25.0	26.5	33.5	35.0	33.0	19.0
5	30.0	26.0	5.5	11.0	7.0		17.0	20.5	24.0	31.5	35.5	36.5	28.0	18.0
6	20.0	25.5	4.5	5.0	10.0		10.0	14.5	23.0	34.5	36.5	39.5	23.5	19.5
7	21.5	24.5	10.0	-1.0	8.0		8.5	10.5	20.0	30.0	31.0	40.5	24.0	21.0
8	26.5	24.0	6.5	6.0	5.5		9.0	11.0	11.0	29.0	23.0	41.5	25.5	23.0
9	25.0	23.5	13.0	7.0	7.0		9.0	11.5	16.5	27.0	23.0	37.0	21.0	21.5
10	29.5	23.5	11.0	4.0	5.0		16.5	12.0	19.5	19.5	23.0	35.0	21.0	11.0
11	23.5	22.0	8.5	-2.0	9.0		15.0	12.0	23.5	20.0	25.5	32.0	23.0	13.5
12	26.0	21.0	10.5	2.0	4.0		14.0	10.0	25.5	23.5	33.5	28.5	22.0	16.5
13	23.0	20.0	10.5	4.5	-1.0		15.5	14.5	30.0	24.5	31.0	26.5	24.0	16.0
14	21.0	13.5	10.0	4.5	-1.0		13.5	15.5	28.0	26.5	30.5	29.0	26.5	15.5
15	21.5	13.0	9.5	3.5	1.0		16.0	14.5	22.0	30.5	32.0	20.0	30.5	15.5
16	20.0	11.0	8.5	6.5	11.0		21.0	10.5	21.0	24.0	34.0	19.5	29.0	17.0
17	21.0	12.0	6.5	10.0	9.5		21.0	8.5	13.5	25.0	33.0	22.0	24.5	18.0
18	21.5	14.5	6.5	5.5	5.5		16.5	12.0	16.5	25.0	29.5	25.0	18.5	17.0
19	24.0	13.5	11.5	5.0	10.5		15.5	15.5	25.5	28.0	24.5	28.5	18.0	16.5
20	19.0	13.5	14.0	6.0	12.0		14.0	14.5	24.0	29.0	21.5	30.5	16.0	19.0
21	20.5	12.0	8.5	6.5	12.0		15.5	12.0	14.0	24.0	25.0	31.0	19.5	20.0
22	23.0	12.0	9.5	9.5			12.0	11.0	20.0	25.5	31.5	25.5	18.0	17.0
23	25.5	10.0	4.0	8.0			11.5	18.0	17.0	19.0	30.5	26.5	12.0	16.0
24	21.0	13.5	8.0	6.5			12.0	15.5	17.0	17.0	31.0	29.5	14.0	14.5

Continued

	1971				1972									
	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec</u>	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sept</u>	<u>Oct</u>
25	19.0	13.5	6.5	6.0			9.0	15.5	20.5	21.0	32.0	31.5	14.0	
26	20.0	11.5	4.0	-2.0			9.0	17.0	25.0	23.5	33.5	35.0	16.5	
27	16.5	6.0	9.0	-4.0			11.0	23.0	29.0	29.0	33.0	36.5	13.0	
28	18.0	3.5	6.5	-7.0			9.0	13.5	32.0	34.5	36.0	37.0	19.0	
29	14.5	5.0	5.0	-4.0		9.0		10.0	35.0	33.0	37.0	35.0	20.0	
30	16.5	-1.0	6.5	-2.0				13.5	31.0	31.0	36.5	26.0	24.5	
31		8.5		4.5					31.0		36.5	26.0		

Minimum Air Temperatures °C 1971-72 Growing Season, ALE

	1971				1972									
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct
1		8.0	4.5	1.0	0.0		-1.0		2.0	10.0	16.5	18.5	17.0	12.0
2		6.0	1.5	1.5	-3.0		-1.0	0.0	9.0	11.5	15.0	20.5	18.5	13.5
3		10.0	4.5	-1.0	-6.0		0.0	0.0	9.0	14.0	14.5	19.0	18.0	11.5
4		13.5	-1.0	-1.0	-4.0		0.0	9.5	12.0	13.0	19.5	20.0	18.0	9.5
5	14.0	14.0	-4.0	0.0	1.0		4.5	7.0	13.5	15.5	21.0	20.5	15.0	7.0
6	10.0	15.5	-1.0	-1.0	3.0		-1.0	3.5	11.5	19.5	21.0	22.0	11.5	5.5
7	8.0	12.0	0.0	-6.0	0.5		-2.0	2.0	9.0	16.5	13.5	23.0	12.0	7.0
8	10.0	11.5	3.5	-6.0	0.0		0.5	1.5	6.5	15.0	12.0	24.5	12.0	8.0
9	15.0	11.0	4.0	0.0	3.0		1.0	0.0	6.5	15.5	11.5	20.0	10.5	9.5
10	14.0	10.5	6.0	-2.0	2.0		5.5	4.0	5.5	10.0	9.5	18.0	8.0	5.5
11	13.5	10.0	4.0	-5.0	2.0		8.0	4.5	8.0	15.0	13.0	15.5	13.5	5.0
12	10.0	9.0	3.5	-4.0	-5.0		7.0	3.0	12.0	8.0	20.0	13.5	11.5	8.5
13	13.5	4.5	2.0	-4.0	-7.0		5.0	3.5	11.5	13.5	20.0	11.0	9.0	9.0
14	10.0	3.5	2.0	1.0	-7.0		3.5	1.5	14.0	13.0	14.0	16.0	11.0	9.0
15	8.0	3.0	2.0	-5.0	-6.0		5.5	3.5	11.0	14.5	19.5	11.0	14.0	5.0
16	11.5	2.0	0.5	-5.0	-5.0		8.0	1.5	11.0	11.5	21.5	9.0	14.5	5.0
17	8.0	1.0	-1.0	5.0	-1.0		8.5	0.0	4.5	11.0	20.0	12.0	9.5	6.5
18	6.5	5.0	0.0	0.0	-3.0		7.0	0.5	2.0	13.0	19.5	13.0	8.5	7.0
19	9.5	6.0	3.0	-2.0	6.5		4.0	5.5	9.0	14.5	14.0	15.5	8.5	4.5
20	10.0	3.5	4.5	3.0	6.5		3.5	2.0	13.0	15.0	12.0	15.5	8.0	5.5
21	5.5	2.0	2.0	4.0			7.0	0.0	10.0	12.0	13.0	16.0	8.5	9.5
22	8.0	7.0	0.0	3.0			6.0	-2.0	6.5	10.0	16.0	16.0	7.0	7.0
23	10.5	4.0	-1.0	0.5			3.5	3.5	6.0	9.5	18.5	14.0	5.0	8.0
24	11.0	2.0	-1.0	2.0			0.5	5.5	6.0	9.0	17.0	16.0	3.5	4.5

Cc ued

	1971				1972									
	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec</u>	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>	<u>Oct</u>
25	11.0	3.0	0.0	-4.0			-1.0	4.5	8.0	9.5	14.5	16.5	1.5	
26	8.5	1.0	1.5	-9.0			-3.0	1.5	10.5	8.5	16.0	19.0	4.5	
27	10.0	-1.0	3.5	-10.0			-1.0	6.5	13.5	11.5	15.0	20.0	3.5	
28	8.0	-4.0	1.5	-9.0			-1.0	3.5	20.0	15.5	18.5	22.0	6.0	
29	6.0	-4.0	1.0	-9.0		1.5		-1.0	20.5	16.0	23.0	21.0	5.0	
30	6.5	-2.0	0.0	-8.0			/	-1.0	17.0	15.5	21.0	15.0	7.0	
31		-4.0		-4.0					15.0		22.0	15.5		

Maximum Soil Temperature (1 decimeter deep)

	1971				1972									
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct
1		19.0	6.5	2.0		-4.0	3.0	14.5	19.5	27.0	31.5	36.0	30.0	21.0
2		19.0	7.0	1.0		-6.0	4.0	14.5	21.5	28.5	31.5	36.5	31.0	21.5
3		19.5	7.0	.5		-7.0	3.0	15.0	23.0	25.5	31.5	36.0	32.0	21.5
4		23.0	9.5	.0	-3.0	-6.0	3.5	15.5	24.0	25.5	32.0	37.0	33.0	19.0
5	28.5	22.0	6.0	2.0	-2.0	-6.0	7.0	14.5	24.0	29.0	34.0	38.0	30.0	18.5
6	24.5	21.0	3.5	2.0	-2.0	-4.0	8.0	14.5	23.5	32.0	35.0	38.5	28.5	15.0
7	25.5	22.0	4.5	.5	-2.0	-3.0	6.5	12.0	23.0	31.0	33.0	39.5	27.0	19.5
8	26.5	22.0	5.5	-1.0	-2.0	-2.0	6.0	11.5	20.0	32.0	29.5	39.0	27.0	19.0
9	27.0	21.5	5.5	-1.0	-2.0	-2.0	6.0	13.0	18.0	29.0	28.0	39.0	26.0	20.0
10	28.0	21.0	7.0	-1.0	-1.0	-2.0	10.0	14.0	24.0	26.5	27.0	38.0	25.5	17.0
11	27.0	20.5	6.5	-1.0	-1.0	-2.0	9.5	13.5	24.5	23.5	26.5	37.0	24.5	13.0
12	26.0	19.5	7.0	-1.0	-1.0	-1.0	8.5	11.5	26.5	25.0	29.0	35.5	24.0	15.5
13	25.5	18.5	6.5	-1.0	-1.0	0	11.0	15.5	28.0	28.0	31.0	32.0	26.0	15.5
14	25.5	16.5	6.0	-1.0	-2.0	0	10.0	13.5	28.0	28.0	33.0	31.0	27.0	14.5
15	24.5	14.5	8.5	-1.0	-2.0	3.0	10.5	15.0	24.5	31.0	34.0	29.5	27.0	15.5
16	22.0	13.5	6.0	-1.0	-2.0	4.0	15.0	14.5	22.0	29.5	35.0	25.5	28.5	16.0
17	22.0	12.0	3.5	0	-2.0	.0	15.5	12.0	19.5	29.0	35.0	28.5	26.5	15.5
18	23.0	13.5	3.5	0	-2.0	.5	13.5	16.0	20.0	30.0	33.5	29.0	24.0	15.5
19	23.0	11.0	6.0	0	-1.0	2.0	13.5	14.5	22.0	30.0	31.6	29.5	22.0	15.5
20	21.5	11.5	9.5	.5	.0	4.5	14.5	15.0	23.5	28.5	27.0	32.0	19.5	15.0
21	22.0	12.0	6.0	.5	1.0	1.0	13.5	14.5	20.5		26.5	33.0	18.5	16.0
22	23.0	11.5	5.5			3.0	11.5	15.5	19.0		30.5	29.0	19.0	16.0
23	22.0	10.5	3.0			5.0	13.5	15.5	20.5		30.0	31.0	15.5	15.0
24	22.0	11.5	2.0			4.0	11.0	16.0	19.0		28.5	31.5	15.5	14.5

	1971				1972									
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
25	20.0	9.5	3.0		-1.0	4.5	10.5	15.0	24.5		33.0	33.5	16.5	13.5
26	21.5	11.5	3.5		-1.0	4.0	11.0	19.0	26.0		34.5	34.0	18.0	13.0
27	19.5	9.0	4.0		-3.0	7.0	11.5	21.0	28.0	29.5	34.5	35.0	16.0	10.5
28	18.0	7.0	4.0		-4.0	9.0	13.5	16.5	30.5	32.0	36.0	35.0	16.0	9.0
29	16.0	5.0	4.5		-5.0	7.0	13.5	14.0	31.5	33.5	37.0	35.0	18.0	
30	17.0	4.5	4.5		-6.0		14.5	16.5	30.0	32.0	38.0	31.5	20.0	
31		3.5			-5.0		15.5		29.5		36.5	30.0		

Minimum Soil Temperature (1 decimeter deep)

	1971				1972									
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
1		11.0	3.5	1.0		-7.0	1.0	10.0	10.0	22.0	23.5	28.5	23.5	14.0
2		11.5	3.0	0		-9.0	.5	7.0	13.5	21.5	23.0	29.0	23.5	15.0
3		13.0	5.0	0		-10.0	.5	5.5	15.0	21.5	23.0	28.5	24.0	15.0
4		15.5	5.5	0	-3.0	-9.0	.0	9.0	16.5	20.0	24.5	28.0	24.5	15.5
5	17.0	16.5	2.0	0	-3.0	-6.0	1.5	11.0	17.0	21.5	25.0	29.0	25.5	13.5
6	18.5	17.0	.5	.5	-2.0	-6.0	4.0	9.0	17.0	24.5	28.0	29.5	22.0	11.5
7	15.5	16.5	1.5	-1.0	-2.0	-4.0	.5	7.0	17.0	26.5	25.5	30.0	21.5	12.0
8	16.5	16.0	3.0	-1.0	-2.0	-2.0	1.0	7.0	14.5	24.5	23.0	31.0	21.0	13.0
9	20.0	15.5	3.5	-1.0	-2.0	-2.0	2.6	5.5	10.5	24.0	20.5	31.5	20.0	15.0
10	19.5	15.5	5.5	-1.0	-2.0	-2.0	4.5	7.0	9.5	21.0	21.0	30.0	18.5	12.0
11	21.0	16.0	5.0	-1.0	-2.0	-2.0	6.0	9.5	13.5	18.5	21.0	30.0	19.5	10.0
12	19.0	15.0	5.0	-1.0	-1.0	-2.0	7.0	9.0	16.0	18.0	22.0	28.0	20.5	10.5
13	19.5	15.5	4.5	-1.0	-2.0	-2.0	7.0	6.5	18.0	20.0	24.5	25.0	18.0	12.0
14	18.5	12.0	3.0	-1.0	-2.0	-1.0	4.5	8.5	20.0	21.0	24.0	25.5	19.0	12.0
15	16.5	12.0	4.0	-1.0	-3.0	-1.0	5.0	10.0	19.5	22.0	25.5	24.5	20.0	10.0
16	17.0	9.5	2.0	-1.0	-3.0	.0	6.5	9.0	16.0	23.0	26.5	17.0	21.5	9.5
17	15.5	8.5	1.0	-1.0	-2.0	-1.0	8.5	8.0	14.0	21.5	27.0	18.5	20.5	10.0
18	15.0	-9.5	.5	.0	-2.0	-1.0	10.0	7.0	10.5	22.0	28.0	18.5	19.0	10.0
19	15.5	10.5	1.5	-1.0	-2.0	0	8.0	8.0	14.0	23.0	24.5	21.0	18.0	10.0
20	18.0	8.5	5.5	-1.0	-1.0	0	6.0	9.0	17.0	23.5	23.5	21.5	16.5	9.5
21	14.5	6.5	3.5	0	0	0	8.0	10.0	12.0		21.0	23.5	14.5	11.5
22	15.0	9.0	1.5			0	5.0	7.0	11.0		22.0	24.0	12.0	10.5
23	16.0	9.5	1.5			0	6.5	9.0	11.0		24.0	21.0	11.0	11.0
24	18.0	6.0	.5			0	7.0	11.5	11.5		24.5	23.0	9.0	9.0

1971					1972									
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
25	17.0	6.5	1.0		-1.0	0	4.0	10.5	12.0		23.0	24.0	8.5	8.0
26	15.5	9.0	2.0		-3.0	0	3.0	9.0	15.5		25.0	25.0	9.0	9.5
27	15.5	6.0	2.0		-6.0	3.5	3.5	11.5	18.0	19.5	25.5	26.0	9.5	6.5
28	13.5	3.5	3.0		-7.0	6.5	4.0	13.5	20.5	20.5	26.5	26.5	11.0	6.0
29	10.5	1.0	3.5		-7.0	1.0	5.5	9.5	22.0	23.0	28.5	27.0	11.0	
30	10.5	4.0	1.5		-9.0		6.0	8.5	23.0	24.0	29.0	26.0	12.0	
31		3.0			-7.0		7.0		25.0		29.5	24.0		

Precipitation Measured in Inches 1971-72 Growing Season - ALE

	1971			1972								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1											0.00	
2		0.00						0.02				
3										0.00		
4				0.17			0.01					
5												0.00
6									0.09			
7			0.52			0.29						
8					0.04						0.00	
9								0.56				
10												
11				0.00			0.10			0.08		
12												0.00
13									0.04			
14			0.60			0.47						
15					0.00						0.01	
16		0.12						0.07				
17												
18				0.00			0.03			0.00		
19												0.00
20								0.05				
21						0.00						
22					0.05						0.35	
23		0.00						0.79				
24				0.42								
25							0.02			0.02		

	1971			1972								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
25							0.02			0.02		
26												0.01
27									0.43			
28						0.02					0.00	
29					0.01							
30		0.45						0.00				
31				0.00								
Total	0.00	0.57	1.12	0.59	0.10	0.78	0.16	1.44	0.61	0.10	0.36	0.01