HERBAGE RESPONSE TO STRIP-CUTTING A PONDEROSA PINE WATERSHED IN CENTRAL ARIZONA

A Thesis

Presented to the Graduate Faculty

Northern Arizona University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

William H. Kruse

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HERBAGE RESPONSE TO STRIP-CUTTING A PONDEROSA PINE

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ABSTRACT

A 1119-acre ponderosa pine watershed in north-central Arizona was strip-cut, alternating 120-foot wide uncut forest strips with 60-foot wide strips cleared of forest. This treatment resulted in a significant increase in the herbaceous understory plant community. Total grass and forb components were significantly higher on the cleared strips than on the uncut strips for each sampling year following the initial treatment.

The sampling design was developed to evaluate effects between two soil types (Brolliar and Sponseller) and two aspects (north and south). Essentially no effect of soil or aspect could be determined. The influence of position was evaluated by establishing nine discrete positions along the sampling sites from the center of the left uncut strip, across the cut strip itself, and into the center of the right uncut strip. Tests among the nine positions determined which areas of the sampling sites contributed significantly to the increases in the herbaceous plant community. A definite increase in understory biomass, occurring at the interface of cut and uncut forest, was established.

An ordination technique, reciprocal averaging, was used to examine differences among sampling sites and among species. While the ordination technique was successful in isolating some groups of sites and species, these groups could not be associated with the soil and site characteristics that were measured.

Some options influencing range and wildlife forage management were identified and related to this type of treatment.

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Chapter 1

INTRODUCTION

The Beaver Creek Pilot Watershed Project was initiated in 1957 by the USDA Forest Service to evaluate the possiblity of treating watersheds to increase water yields and to provide more grass for grazing (Brown et al. 1974). The research area was located in pinyon-juniper (Pinus spp.-Juniperus spp.) woodland[1], alligator juniper (Juniperus deppeana, Steud.) woodland, and ponderosa pine (Pinus ponderosa, Laws.) forest ecosystems of central Arizona, 35 miles south of Flagstaff. The purpose of the project was to observe the effects of vegetation changes on water yield, soil, timber, forage, wildlife, and recreation, and to determine whether these changes increased the risk from fire, insects, and diseases. Eleven watersheds were treated between 1959 and 1975 and included a variety of designs of overstory modification. These modifications included complete overstory removal, various strip-cutting designs, and several levels of thinning.

One specific ponderosa pine forest treatment, where the cutting pattern consisted of alternating strips of timber with strips cleared of timber, was the focus of the research reported in this paper. Although the treatment was designed to increase water yield, the effect of this treatment on the range resource was also important.

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[1]Nomenclature follows Kearney and Peebles (1969). A list of scientific and common plant names used in this text can be found in the Appendix.

The cutting pattern of alternating strips might show herbage responses to be different than responses from clearcutting, patch cutting, or thinning. Therefore, the objectives of this research were to:

1. evaluate the effects of the strip-cut treatment on range resource values, i.e. total aboveground understory productivity and livestock, deer, and elk forage production.
2. determine the relationships of the soils and sites of the watershed to the effects of the treatment, and how these relationships affected the recovery of the understory plant community.
3. investigate the reciprocal averaging ordination technique as a method for evaluating plant response to a strip-cut treatment.

The increased demand on the range resource requires improved land use planning and the application of new methodologies for more efficient utilization of this resource than now exist. An evaluation of the effects of this strip-cut treatment should not only provide the range manager with information on the quantity and quality of the range resource, but also aid the land management planner by providing alternative management options concerning this type of treatment.

Chapter 2

LITERATURE REVIEW

Background

In 1956, the University of Arizona's Department of Agricultural Economics published the Barr report (Barr 1956) which outlined the status of the water resources in arid Arizona. It reported the available water sources, water transportation systems, and water needs in Arizona. The report also projected the future demand for water and suggested methods for improving water yields. One important suggestion was the possibility of treating the overstory vegetation to increase water yields.

Modification of the overstory vegetation was to be tested in several ecosystems with the objective of improving a variety of resource yields. In ponderosa pine and other coniferous forests, for example, timber and range values might also be improved while increasing water yields. The initial emphasis, however, was placed on watersheds at lower elevations because the potential for improvement of these range resources was higher than the coniferous forests.

Therefore, methods which aided in range restoration or the conversion of chaparral and pinyon-juniper woodlands to grass were initiated. Researchers and range managers have suggested that overgrazing and improper range management encouraged the encroachment by brush and woodland species into grasslands (Glendening and Paulsen 1950, Martin et al. 1951, Parker and Martin 1952). Arnold (1955) and

LeCrone (1959) showed that mechanical control of juniper invasion significantly increased forage production on the Fort Apache Indian Reservation. Decline of rangeland forage by woody invasion has also been documented (Parker 1954). Dortignac (1956, 1960) suggested that water yields may also increase following control of woody species. Therefore, large scale cabling, root plowing, burning, and herbicide spraying were conducted on many woodland and chaparral areas.

As part of the Arizona Watershed Program, experimental watersheds were set up to evaluate the impact of these treatments in many vegetation types in Arizona (Kennedy 1959, LeCrone 1959, Reynolds 1959). Some vegetation types and areas included in the program were ponderosa pine in the White Mountains of eastern Arizona (Rich 1972) and on the Apache Indian Reservation, juniper watersheds (also located on the Apache Indian Reservation), sub-alpine conifer watersheds in the White Mountains, and chaparral watersheds in central Arizona. In north central Arizona the Beaver Creek Watershed Program, also part of the Arizona Watershed Program, included juniper and ponderosa pine vegetation types (Brown et al. 1974).

Overstory Vegetation Treatments at Beaver Creek

Overstory treatments in the pinyon-juniper woodland watersheds at Beaver Creek were not very successful from an economic perspective. For example, although Clary et al. (1974) showed significant increases in perennial grasses, forbs, and half shrubs following all juniper tree removal projects on Beaver Creek, they concluded from a benefit-cost analysis that, "...juniper control is not economically feasible for areas that have responses similar to these watersheds." Other studies on pinyon-juniper watersheds suggest a variable success rate as well. Arnold and Schroeder (1955) estimated ten years would be required for sites on the Fort Apache Indian Reservation to reach maximum herbage production following tree removal. Chilson (1964) and Robinson (1965) estimated livestock carrying capacity increased several fold following juniper control and reseeding projects. Aro (1971) evaluated pinyon-juniper conversion attempts in four states and found considerable variation in success from one area to another. These reports suggest that successful projects depend on time, type of treatment, and site conditions. Since pinyon-juniper treatments appeared economically unsuccessful on the Beaver Creek Area, treatment emphasis was placed on the ponderosa pine watersheds.

Nevertheless, some important aspects of the pinyon-juniper work were included in the ponderosa pine watershed evaluation. Arnold et al. (1964) found less regeneration of the treated tree species on deeper soils. Also, the grass seeding not only hindered regeneration of those tree species, but also enhanced the forage component, which competed significantly with annuals and weedy forbs (Clary et al. 1974, Arnold and Schroeder 1955). These studies suggested that an intensive examination of site characteristics was necessary for evaluating the watershed treatments. Therefore, elements of pinyon-juniper site classification became an important aspect of the ponderosa pine watershed evaluation.

Chapter 3

STUDY AREA DESCRIPTION AND TREATMENT BACKGROUND

The study watershed (Watershed 9) was one of 20 study watersheds on the Beaver Creek Area, located on the Coconino National Forest in north-central Arizona.

The soils, developed from basalt and cinders, are primarily silty clays and silty clay loams less than 2.5 feet deep (Williams and Anderson 1967).

Monthly mean temperatures vary between a December and January mean of 29°F and a July mean of 66°F (Brown et al. 1974).

The Beaver Creek Study Area receives an annual average of 25 inches of precipitation distributed between two major precipitation seasons (Brown et al. 1974). Sixty-four percent falls during the winter (October through April) as snow. Thirty-two percent occurs during the summer rainy months of July through September. The remainder occurs during the May-June drought period.

Brown et al. (1974) describe the area as a high plateau with sloping mesas and breaks, steep canyons, and valleys. The elevation of the ponderosa pine watersheds varies from 6,800 feet to 8,000 feet.

Ponderosa Pine Forest Treatments

Eight ponderosa pine watersheds were treated on the Beaver Creek Area. The treatments consisted of cutting the overstory in various patterns to increase water yield. Kittredge (1948) estimated that overstory intercepts 18 to 20 percent of falling precipitation.

Evapotranspiration of soil moisture and transpiration by trees also reduces significant amounts of water that would otherwise be available for runoff. Brown et al. (1974) determined that tree removal treatments on Beaver Creek significantly increased water yields.

Removal of the overstory can increase water and forage responses, and may also benefit other major resources. Although complete removal of ponderosa pine overstory produced maximum water and herbage yields (Brown et al. 1974), Rich (1972) suggested that strip-cuts, patch cuts, or thinning could also be effective. Schubert (1974) noted that intensive forest management practices, such as thinning, could also increase timber production. Reynolds (1962) found that logging increased forage production for deer and elk. Reynolds (1962) and Patton (1969) also determined that openings, cut or natural, improved deer habitat in ponderosa pine forests.

One-third of Watershed 9 was clearcut in uniform strips, 60 feet wide. According to Kittredge (1948), this reduction in overstory should reduce interception and evapotranspiration by one-third. Berndt (1965), in a study of snow behavior on clearcut blocks in Wyoming, found increased snow accumulation in cut blocks as compared to uncut stands. Rothacher (1965) found snow accumulation to be 35 percent higher in a cut strip 2-chains wide than in uncut forest, suggesting increased melt and runoff from the cut strips. Weitzman and Bay (1959) determined that more snow accumulated in cut strips than in uncut stands when the strips were cut on east to west facing sites. On Watershed 9, emphasis was placed on cutting strips downhill to enhance runoff into stream channels (Brown 1967).[2]

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[2]Brown, Harry E. 1967. Watershed 9 treatment plan. Rocky Mountain Forest and Range Experiment Station. On file Flagstaff, Arizona.

Relationships of animal use to plant development may be affected by the edges produced by the cutting method. Strip-cutting increases the interface of forest stand to forest opening (edge effect) many hundreds of times. Narrow cleared strips, dominated by herbaceous growth, alternating with uncut forest-dominated strips, may show plant responses which differ from other cutting practices because the forest trees may influence plant responses from both sides of the cut strip. Arnold (1964) found that herbaceous production increased, and species composition changed, with increasing distance from juniper trees. He suggested that this was due to soil moisture competition from tree roots. With respect to animal use, Reynolds (1966) and Wallmo (1969) have shown plant utilization by elk and deer to be greater near the edge of openings than in untreated forests or in the centers of forest openings.

Since the strip-cutting treatment was applied on a variety of soil types, slopes, and topographical positions, the effects of these site factors could also be evaluated. For example, Clary et al. (1966) showed increased sampling precision after grouping sites by soil characteristics, slope, and topographical position. Williams and Anderson (1967) described two soil types on Watershed 9, and Clary (1964), using an earlier soil survey, determined that herbage yields differed between these two soil types.

Chapter 4

METHODS

Sampling Design

The sampling design was chosen to measure the herbage responses on two different soils and two different aspects following a strip-cut treatment. In evaluating the effects of this treatment on understory productivity, 24 clusters of 27 plots each were located throughout the watershed. To evaluate the influence of the soil and site variables, 12 of the 24 clusters were located on Siesta-Sponseller soils and 12 were located on Brolliar soils. Six of the 12 on each soil type were located on warm (south to southwest aspect) sites while the other six were located on cool (north to northeast aspect) sites. Thus, these sampling clusters were distributed in four strata such that:

Clusters 1- 6 = Siesta-Sponseller soil/warm site
Clusters 7-12 = Siesta-Sponseller soil/cool site
Clusters 13-18 = Brolliar soil/warm site
Clusters 19-24 = Brolliar soil/cool site

Soil and topography maps aided in determining strata. The four groups of six clusters each were randomly selected from aerial photos before locating them on the ground. These clusters were set out in the spring of 1969 following treatment.

Each sampling cluster was a 60- by 180-foot rectangle oriented perpendicular to the cut strip and divided into nine positions (subplots), each 20 feet wide and 60 feet long (Figure 1). These positions

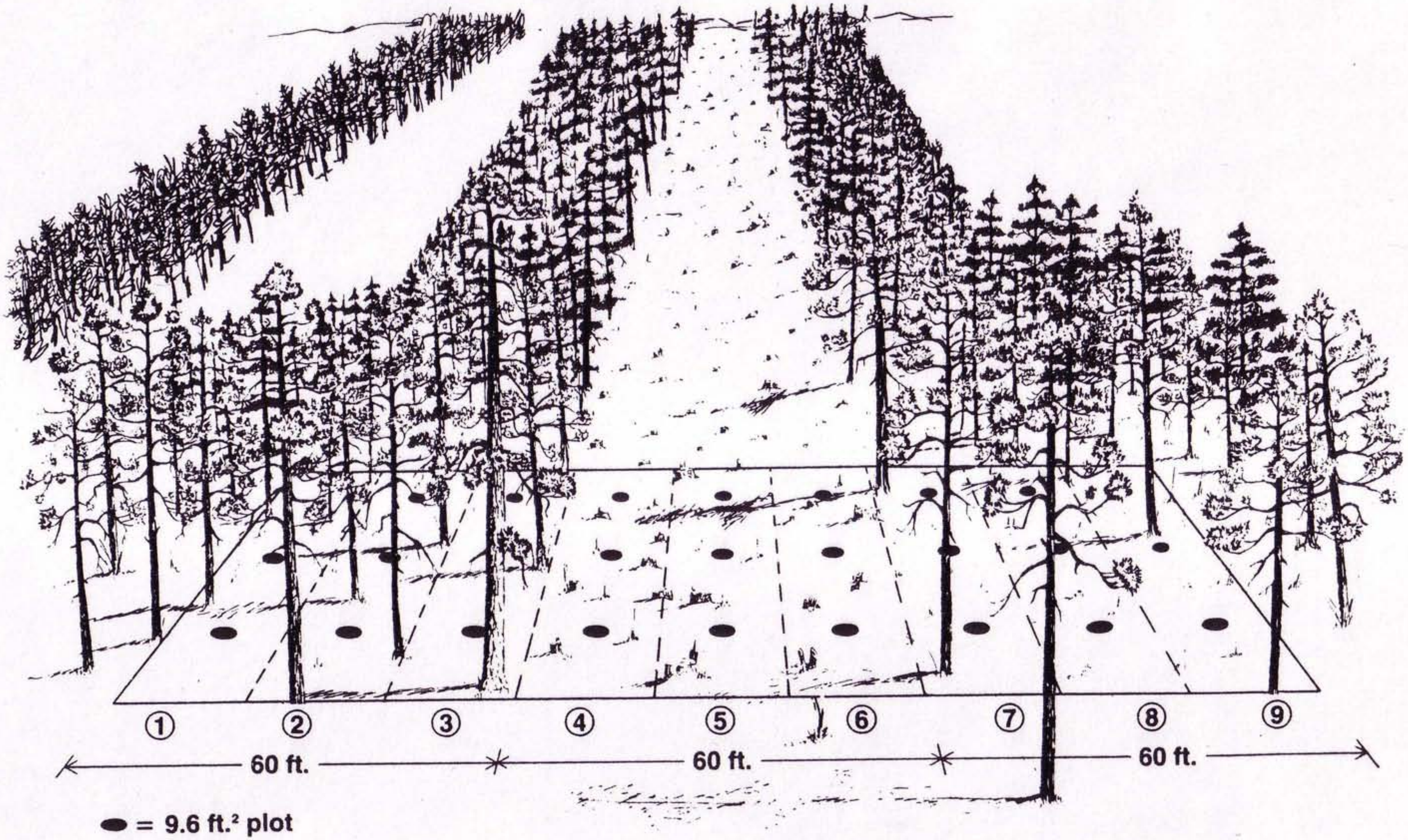

Figure 1.--Cluster layout, showing nine positions, in relation to timber cleared strips and uncut strips

provided a base for the study of herbage production, from the center of one leave strip across the cut strip to the center of the next leave strip. Within each 20-foot wide position, a line was randomly located upon which three 9.6 square foot plots were systematically distributed. Within these sample plots, field weight for each species was estimated and recorded. Clip plots were randomly selected outside each cluster. These plots were estimated, clipped, oven dried, and weighed to develop correction factors for conversion of field weight estimates to oven dry weights.

Forage plants for livestock consisted primarily of perennial grasses, forbs, and shrubs commonly known to be important components in livestock diets (U.S. Department of Agriculture, Forest Service, 1980).[3] Forage for elk and deer was determined from Neff (1980a). These forage plants made up the total aboveground understory biomass estimated from each plot. The perennial grass group was subdivided into cool and warm season groups based on the grasses' primary season of growth. The analysis procedures then utilized the following groups for treatment response: 1) total aboveground understory biomass (overall treatment response), 2) perennial grasses (cool and warm season for spring and summer livestock and elk forage), 3) forbs (deer forage), and 4) shrubs (browse).

Analysis Methodology

Two analysis of variance (AOV) procedures were performed. The first, a one-way AOV, was preliminary and tested for differences

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[3]U.S. Department of Agriculture, Forest Service. 1980. Allotment analysis handbook. Region 3, Albuquerque, N.M.

between years. Since each year was different, a second analysis of variance was used to test for differences in the levels of biomass of the various plant classes as related to strata, position, and interaction. This model was a one factor repeated measures design with position nested within strata. The independent variables tested are expressed in the following AOV table:

Source	d.f.		
Strata	3		Fixed
Soil		1	
Aspect		1	
Soil * Aspect		1	
Error 1	20		
Position	8		
Strata * Position	24		Fixed nested within strata
Soil * Position		8	
Aspect * Position		8	
Soil * Aspect * Position		8	
Error 2	592		
TOTAL	647		

To analyze such complex ecological interactions requires many techniques. Gauch (1977) suggested that ordination techniques might be useful to relate many samples to one another as well as species to one another. Patterns of samples or species might then relate to patterns of environmental factors. Bray and Curtis (1957) successfully used ordination techniques to relate species to environmental gradients.

Ordination techniques were used to examine relationships among species and among sites (clusters). Of the four ordination techniques described by Gauch (1977), reciprocal averaging (RA) was used because it simultaneously ordinates species and sites and because it works well in situations where major environmental factors (in this case precipitation and elevation) do not vary greatly.

Reciprocal averaging was applied to four matrices: a) clusters by individual species in the uncut portions of the sampling strips, b) clusters by individual species in the cut portions of the sampling strips, c) clusters by species classes (total, grass, forb, shrub) in the uncut portions of the sampling strips, and d) clusters by species classes in the cut portions of the sampling strips. In each case, the variable (species or species classes) values were oven dry weights (lbs/ac). The resultant ordinations were then inspected to determine if clusters from the same strata tended to occur together in the ordinations. The ordinations were also inspected to determine if species or species classes occurred in distinct groups or if they were related to the pattern of clusters in any way. Correlation coefficients between environmental variables and cluster position on the RA axes were calculated in an attempt to determine if the RA axes were related to any environmental gradient.

Chapter 5

RESULTS

Aboveground Understory Biomass Production on Watershed 9 Following Treatment

An analysis of variance indicated that production values for all herbage classes, except 1969 and 1970 shrub classes, were significantly different between the sampling years (Table 1). These values represent the yearly average for the overall treated watershed, and the trend was an increase in aboveground biomass productivity for each plant class for each subsequent year. Since the warm season plant class constituted such a small portion of total grass production (less than 5 percent), it was excluded from the analyses.

Table 1. Annual watershed aboveground understory biomass production (lbs/ac) values for each year and plant class group. All groups are different (p<.01), except 1969 and 1970 shrub classes, as indicated by the analysis of variance

Year	Total	Grass	Forb	Shrub	Cool season grasses
1969	98	32	53	13	30
1970	152	50	76	26	49
1973	298	95	153	51	93

The analysis showed that differences which occurred between 1969 and 1970 in the shrub class were significantly different from the 1973 shrub class but not from each other. All other plant class groups were significantly different from year to year. Aboveground biomass production increased over the four year sampling period.

Since these yearly differences in aboveground biomass production existed, tests to determine the effects of soil and aspect on understory production were conducted within each year. This analysis compared the two soils, the two aspects, and their interactions. No significant differences were found in herbaceous biomass production for any plant class with respect to soils, aspect, or their interaction.

The analysis of variance also compared positions, position/soil, position/aspect, and position/soil/aspect interactions (Table 2). The analysis shows that highly significant differences existed between positions ($p<.01$) for all plant classes within each year, with the exception of shrub production. However, when soil and aspect interacted with position, the differences were less significant, and in many cases not significant within each parameter. Since soil and aspect were not shown to affect production, and position was shown to have such a strong effect, differences within position interactions may be more a result of the position effect than soil or aspect.

To determine which positions differed from each other, six contrasts between positions, within each year, were performed on each plant group except shrubs. Since shrubs did not show production level changes across position or any interaction, they were eliminated from the contrasts.

Table 2. F-values resulting from analysis of variance testing for differences between positions and position interaction with soil, aspect, and soil and aspect. Tabular F (8,592 d.f.) (p = .05) = 1.94. Tabular F (8,592 d.f.) (p = .01) = 2.51

	Position			Position/soil		
	1969	1970	1973	1969	1970	1973
Total production	18.45**	15.73**	41.29**	2.46*	2.88**	1.22
Grass production	9.48**	5.91**	34.54**	2.25*	.50	2.13*
Forb production	19.47**	27.29**	52.14**	1.46	4.51**	.63
Shrub production	.79	1.34	.90	.78	.89	.49
Cool season grass	10.26**	5.80**	35.29**	2.20*	.46	2.26*
	Position/aspect			**Position/soil/aspect**		
	1969	1970	1973	1969	1970	1973
Total production	1.39	.64	3.07**	1.40	.74	1.03
Grass production	2.01*	1.80	2.05*	3.84**	2.26*	1.52
Forb production	1.88	.18	3.39**	.51	.22	1.04
Shrub production	1.45	.58	.71	.80	.92	1.04
Cool season grass	2.38*	1.98*	1.98*	4.21**	2.20*	1.58

**Significant at 0.01 level.

*Significant at 0.05 level.

Comparison of Cut and Uncut Positions

Contrast 1 compared the uncut positions 1, 2, 3, 7, 8, 9 with clear cut positions 4, 5, and 6 while contrast 2 compared the "outermost" uncut positions 1, 2, 8, 9 with clear cut positions 4, 5, and 6. Calculated F-values showed that cut positions, within each year, had significantly greater production than uncut positions (Tables 3, 4).

Comparisons Among Cut Positions

Contrast 3 examined the cut positions 4, 5, and 6 (Table 5). In this comparison the results showed the centermost position (5) to have significantly ($p<.01$) less biomass production than the "edge" cleared positions 4 and 6 in sample year 1969. However, in 1970 and 1973 all plant groups on position 5 (except grass production in 1970) were significantly higher than positions 4 and 6. Production mean comparisons in Table 5 showed that values to the right side of the "vs" (position 5) were significantly depressed in 1969, probably as a result of the piling and burning of slash in the center of the cleared strip. In 1970, values for position 5 were significantly elevated for total production and forb production, but still significantly depressed for grass and cool grass production. However, in 1973 all plant groups had significantly higher net biomass production values on position 5 than on positions 4 and 6.

Table 3. Aboveground biomass production means (lbs/ac) for contrast 1, uncut positions (1, 2, 3, 7, 8, 9) vs cut positions (4, 5, 6)

	1969	1970	1973
Total Production	56 vs 180**	99 vs 257**	144 vs 606**
Grass Production	23 vs 49**	42 vs 66**	45 vs 193**
Forb Production	20 vs 119**	31 vs 164**	57 vs 344**
Cool Season Grass Prod.	21 vs 48**	41 vs 64**	45 vs 190**

Tabular F[(5,2 d.f.)] p = .05 = 5.79 , p = .01 = 13.27
**Significant at 0.01 level
*Significant at 0.05 level

Table 4. Aboveground biomass production means (lbs/ac) for contrast 2, outermost uncut positions (1, 2, 8, 9) vs cut positions (4, 5, 6)

	1969	1970	1973
Total Production	52 vs 180**	95 vs 257**	126 vs 606**
Grass Production	21 vs 49**	38 vs 66*	35 vs 193**
Forb Production	19 vs 119**	32 vs 164**	54 vs 344**
Cool Season Prod.	19 vs 48**	37 vs 64*	34 vs 190**

Tabular F[(3,2 d.f.)] p = .05 = 9.55 , p = .01 = 30.82
**Significant at 0.01 level
*Significant at 0.05 level

Table 5. Aboveground biomass production means (lbs/ac) for contrast 3, edge cleared positions 4 and 6 versus center cleared position 5 for each year

	1969	1970	1973
Total production	220 vs 100**	229 vs 315**	470 vs 880**
Grass production	64 vs 18**	81 vs 37**	131 vs 317**
Forb production	139 vs 79**	116 vs 260**	252 vs 529**
Cool season grass	63 vs 18**	78 vs 37**	127 vs 317**

**Significant at the 0.01 level

Comparison of Cut and Uncut Edge Positions

Contrast 4 compared edge positions (Table 5). Uncut edge positions 3 and 7 were compared to cut edge positions 4 and 6. Cut edge positions (4 and 6) had significantly higher aboveground biomass production for all plant groups than uncut edge positions (3 and 7) for all three years ($p<.01$).

Comparison Among Uncut Positions

Contrasts 5 and 6 compared uncut positions (Tables 7 and 8). In contrast 5, uncut positions 1, 2, 3 (left side uncut positions) were compared to 7, 8, 9 (right side uncut positions). No statistical differences were found between the right and left uncut positions. Contrast 6, however, compared uncut edge position 3 and 7 with innermost uncut positions 1, 2, 8, and 9; in 1970 and 1973 some differences in grass production were measured. In 1970, more cool grass production was measured on the edge uncut positions than on the innermost positions ($p<.05$). In 1973, both grass and cool grass production was higher on the uncut edge positions than on the inner positions ($p<.05$).

Table 6. Aboveground biomass production means (lbs/ac.) for contrast 4 uncut edge positions (3, 7) vs cut edge positions (4, 6)

	1969	1970	1973
Total Production	65 vs 220**	108 vs 229**	181 vs 470**
Grass Production	28 vs 64**	51 vs 81**	68 vs 131**
Forb Production	22 vs 139**	29 vs 116**	63 vs 252**
Cool Season Grass Prod.	28 vs 63**	50 vs 78**	68 vs 127**

**Significant at 0.01 level

Table 7. Aboveground biomass production means (lbs/ac) for contrast 5, left side uncut positions (1, 2, 3) vs right side uncut positions (7, 8, 9)

	1969	1970	1973
Total production	62 vs 51	108 vs 90	136 vs 153
Grass Production	22 vs 24	40 vs 45	44 vs 48
Forb Production	24 vs 17	31 vs 32	58 vs 56
Cool Season Grass Prod.	21 vs 22	39 vs 44	43 vs 47

Table 8. Aboveground biomass production means (lbs/ac) for contrast 6, uncut edge positions (3, 7) vs uncut non-edge positions (1, 2, 8, 9)

	1969	1970	1973
Total Production	65 vs 52	108 vs 95	181 vs 126
Grass Production	28 vs 21	51 vs 38	68 vs 35*
Forb Production	22 vs 19	29 vs 32	63 vs 54
Cool Season Grass Prod.	28 vs 19	50 vs 37*	68 vs 34*

**Significant at 0.01 level

*Significant at 0.05 level

Individual species were not tested statistically because the variation is generally great for the majority of the them. Nevertheless, Tables 9 and 10 show a comparison of average production of some important species between leave strip and cut strip positions for the three sample years. These species are categorized as decreaser or increaser and cool or warm season species. Decreaser species are important climax species for a particular herbaceous plant community suggesting an optimum range condition. Generally, these species are the most palatable forage sources for the grazing animals and their productivity decreases under increased grazing pressure, resulting in a deteriorated range condition. An increase in the productivity of these species suggests an improved or improving range condition. Increaser species are important species in a particular plant community; however, the range condition is more deteriorated than the optimum climax stage.

Table 9. Biomass production (lbs/ac) of important decreaser and increaser grasses in cut strips (CS) and uncut strips (LS) by year. Grasses are identified as cool season and warm season grasses

Graminoids		1969		1970		1973	
		LS	CS	LS	CS	LS	CS
Blepharoneuron tricholepis, (Torr.) Nash	decreaser (warm)	.25	.37	0.27	0.83	.02	.47
Bouteloua gracilis, (H.B.K.) Lag.	increaser (warm)	--	--	0.10	0.27	--	--
Bromus spp.	decreaser (warm)	.20	4.23	1.83	4.33	1.68	13.17
Festuca arizonica, Vasey	increaser (cool)	.88	1.00	1.37	2.30	3.47	1.97
Koleria cristata, (L.) Pers.	decreaser (cool)	.05	.00	.20	0.0	--	--
Muhlenbergia montana, (Nutt.) Hitchc.	decreaser (warm)	1.77	1.30	.70	1.0	.47	2.13
Poa fendleriana, (Steud.) Vasey	decreaser (cool)	1.38	1.30	8.70	5.30	6.18	11.13
Sitanion hystrix, (Nutt.) J.G. Smith	increaser (cool)	9.05	22.73	19.00	35.83	24.58	122.63
Sporobolus interruptus, Vasey	decreaser (warm)	--	--	.20	.40	0.25	0.13
Carex spp.	increaser (cool)	5.75	8.20	9.88	14.73	9.03	39.07

Table 10. Biomass production (lbs/ac) of important decreaser and increaser forbs in cut strips (CS) and uncut strips (LS) by year

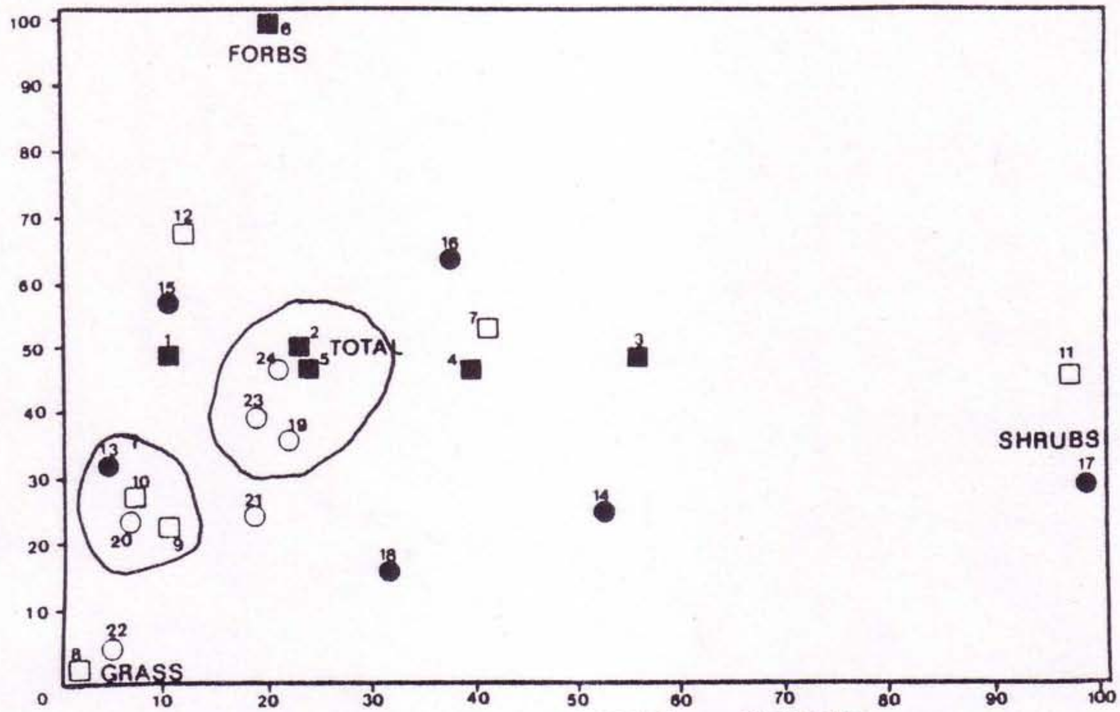
Forbs		1969		1970		1973	
		LS	CS	LS	CS	LS	CS
<u>Epilobium</u> <u>paniculatum</u>, Nutt.	increaser	--	--	.07	.63	0.0	2.43
<u>Geranium</u> <u>fremontii</u>, Torr.	increaser	.43	1.33	.30	1.63	0.53	2.33
<u>Lactuca</u> <u>serriola</u>, L.	increaser	.03	1.50	.05	3.60	0.68	13.67
<u>Lathyrus</u> spp.	decreaser	.93	0.57	.07	.13	--	--
<u>Lotus</u> <u>wrightii</u>, (Gray) Greene	decreaser	.42	0.40	.83	2.40	1.83	13.67
<u>Thermopsis</u> <u>pinetorum</u>, Greene	increaser	.05	0.37	.38	1.50	1.32	4.60
<u>VICI</u> spp.	decreaser	.60	0.60	2.87	1.93	6.62	7.07

These species increase in productivity when the competition from the decreaser species is removed by grazing pressure. Increaser species may also increase with the removal of conditions which previously supported a very poor range condition. Therefore an increase in the productivity of both the decreaser and increaser species groups would suggest an improved or improving range condition.

Results of the Reciprocal Averaging Ordination

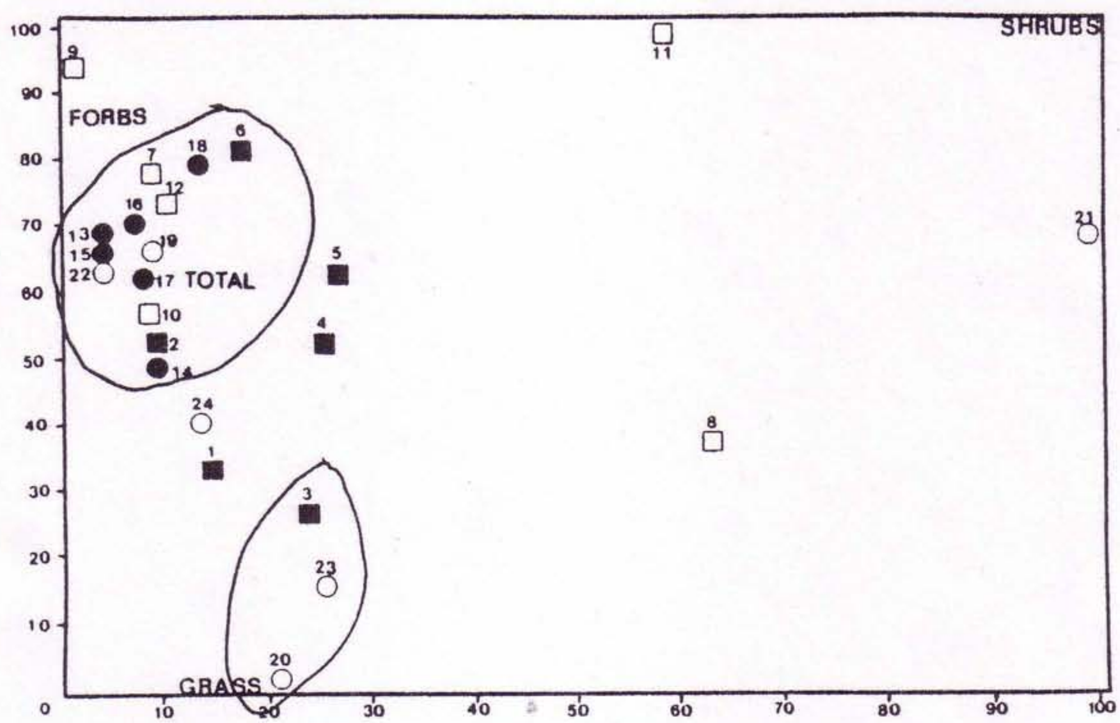
The ordinations were successful in that a distribution of sample points (clusters) relative to species classes suggests "grouping" of similar samples (clusters). Disregarding the outliers for a moment, Figure 2 a,b,e, and f best show grouping because three or four distinct sample groups can be recognized. Figure 2c suggests all lack a pattern of similar symbols, while in Figure 2d, four of the six warm Siesta samples "group" near "total" and four of the six warm Brollier samples "group" near "grass". Symbols were utilized to show clusters from the four strata; clusters with the same symbol did not necessarily occur together in the ordination, suggesting that strata criteria (aspect and soil series) did not always correlate with vegetation similarity as indicated by the ordination. However, there does appear to be some grouping of similar strata, particularly in Figure 2a, b, and f, although all groups contain samples from at least two strata. Most important in these results is the lack of consistency for the groups between years. Had positive gradients been identified, one should expect similar grouping, between years, particularly in the leave strip ordinations.

Distribution of plant classes (total, grass, forb and shrub) in the ordination is more consistent between years and has greater inter-



1969 UNCUT STRIP GROUPS vs SAMPLES

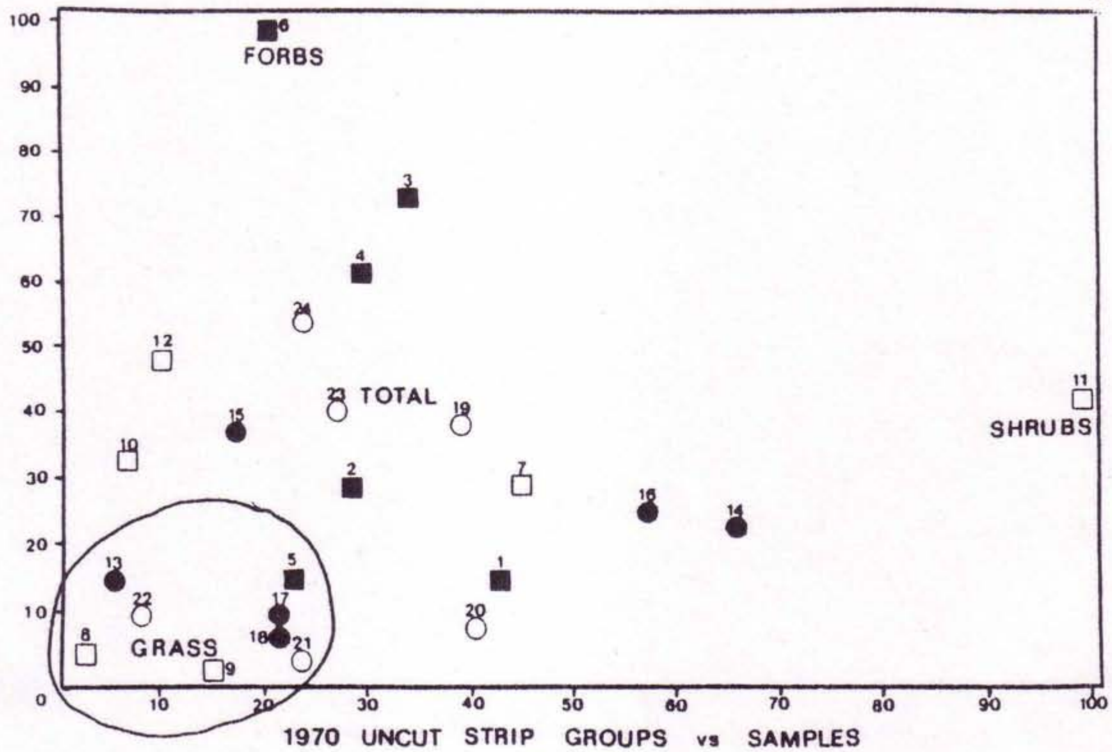
Fig. 2a



1969 CUT STRIP GROUPS vs SAMPLES

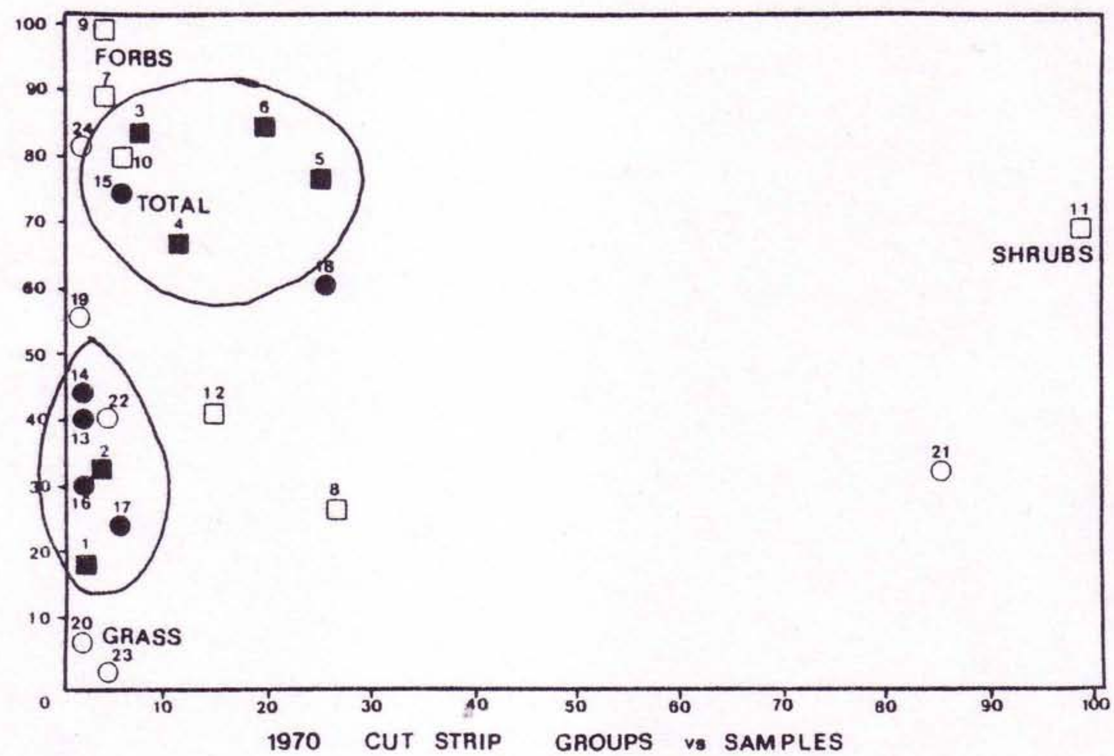
Fig. 2b

Figure 2.--1969 reciprocal averaging ordination of plant groups vs. samples for (a) uncut, (b) cut strips. Proportion of total variance accounted for in first two axes is 100% for both treatments. Numbers refer to samples. Symbols: ■ = warm Siesta, □ = cool Siesta, ● = warm Brolliar, ○ = cool Brolliar.



1970 UNCUT STRIP GROUPS vs SAMPLES

Fig. 2c



1970 CUT STRIP GROUPS vs SAMPLES

Fig. 2d

Figure 2.--Continued. 1970 reciprocal averaging ordination of plant groups vs. samples for (c) uncut, (d) cut strips. Proportion of total variance accounted for in first two axes is 100% for both treatments. Numbers and symbols as in Figure 2a,b.

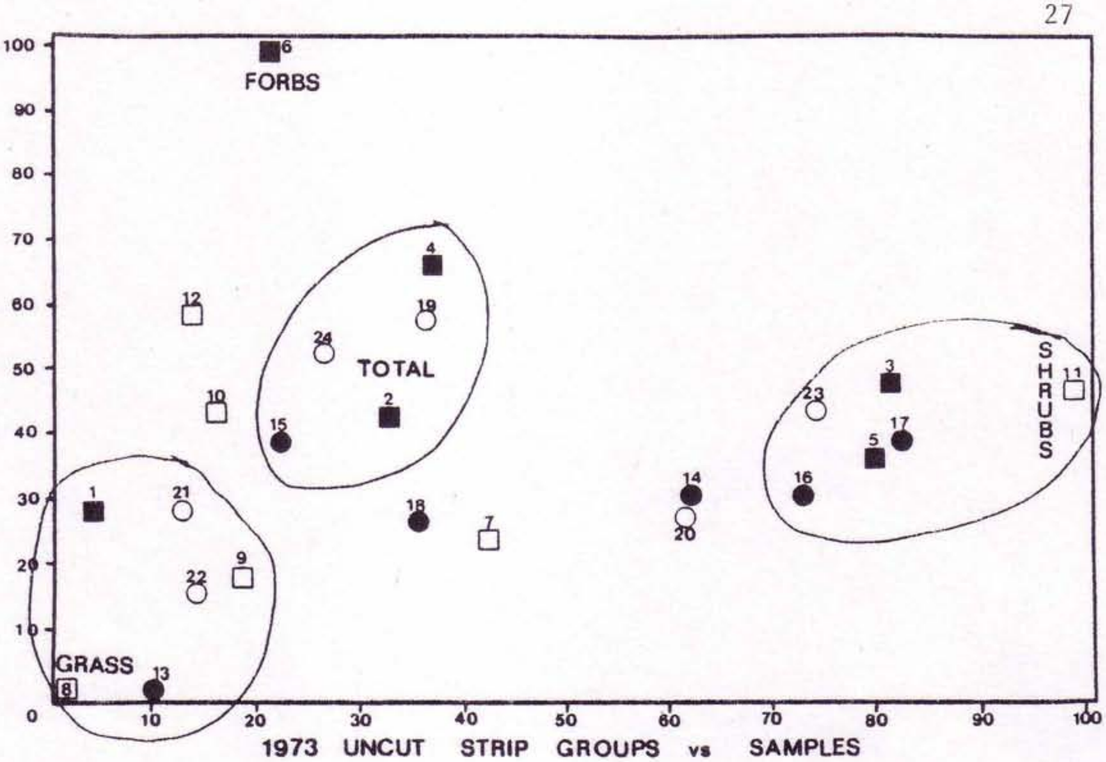


Fig. 2e

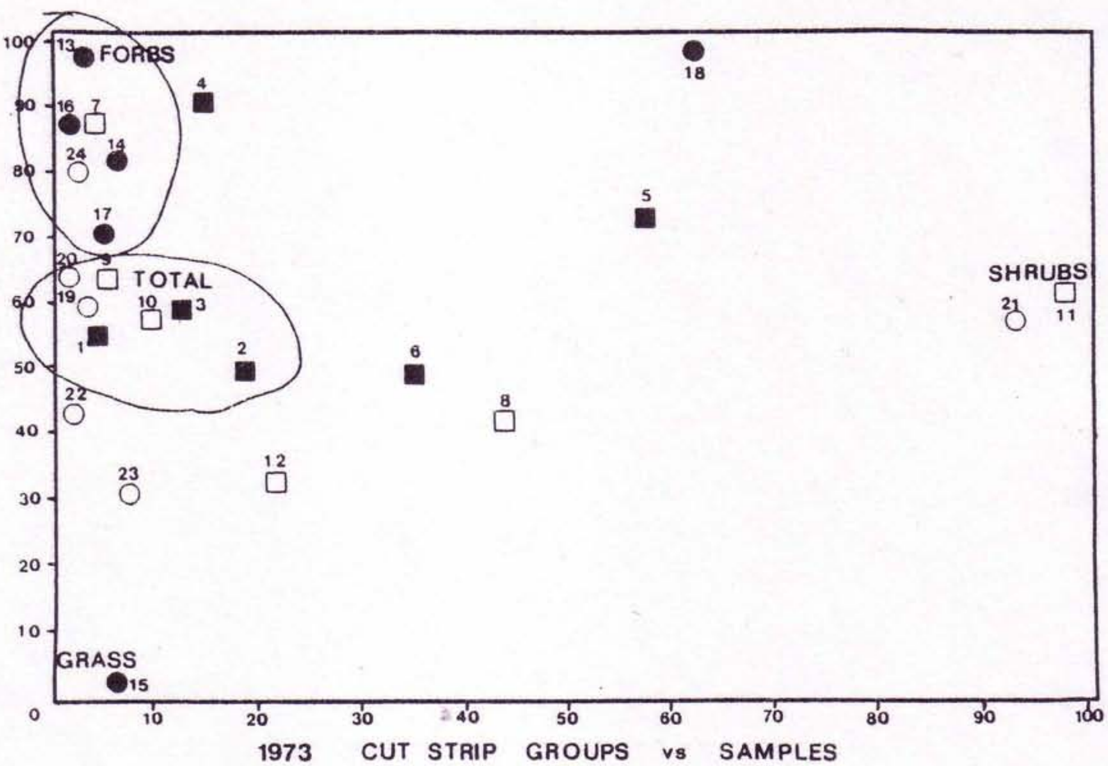


Fig. 2f

Figure 2.--Continued. 1973 reciprocal averaging ordination of plant groups vs. samples for (e) uncut, (f) cut strips. Proportion of total variance accounted for in first two axes is 100% for both treatments. Numbers and symbols as in Figure 2a,b.

pretive value than does distribution of individual samples (Figure 2). The plant classes have a relationship to each other and to outlier samples (clusters). For example, in both the uncut and cut runs, total production is associated with the largest group of samples. Grass, forb, and shrub scores are consistently positioned in the lower left, top left, and far right portions of the ordination, respectively. Associated with these portions in the ordination of uncut strips are clusters 8, 20, 21, and 22 for grass, cluster 6 for forbs, and cluster 11 for shrubs. In the ordinations of cut strips, clusters 15, 20, and 23 are associated with grass; 6, 7, and 9 are associated with forbs; and 11 and 21 are associated with shrubs. Note from Figure 2 that these samples/species class relationships may or may not gravitate from one position of the ordination to another following treatment.

Figure 3 shows the ordination distribution of samples relative to individual species. Nomenclature abbreviations for the more important species are positioned in Figure 3 as a result of the ordination and can be associated with scientific and common names in the Appendix.

Again, disregarding the outliers for a moment, grouping is greatest in Figure 3c, 3d, and 3f, suggesting all species and sample relationships are similar. Figure 3a can be interpreted as a single similar group or may be divided into soil types, while in Figure 3b and 3e, two or more groups appear. Notable in these groups, particularly in Figure 3b, is that similar site symbols dominate two of the groups. Note that individual plant symbols are not consistently associated with similar sample symbols. Should the outliers be classified as a group more grouping could be interpreted than is shown.

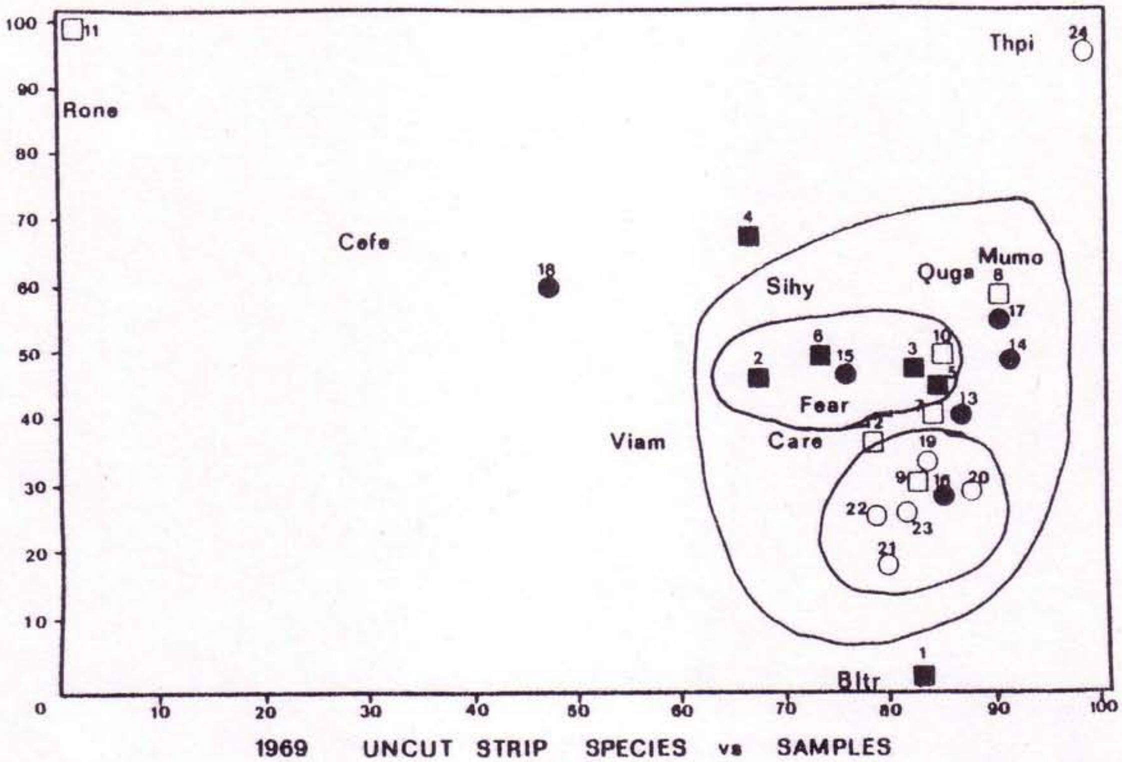


Fig. 3a

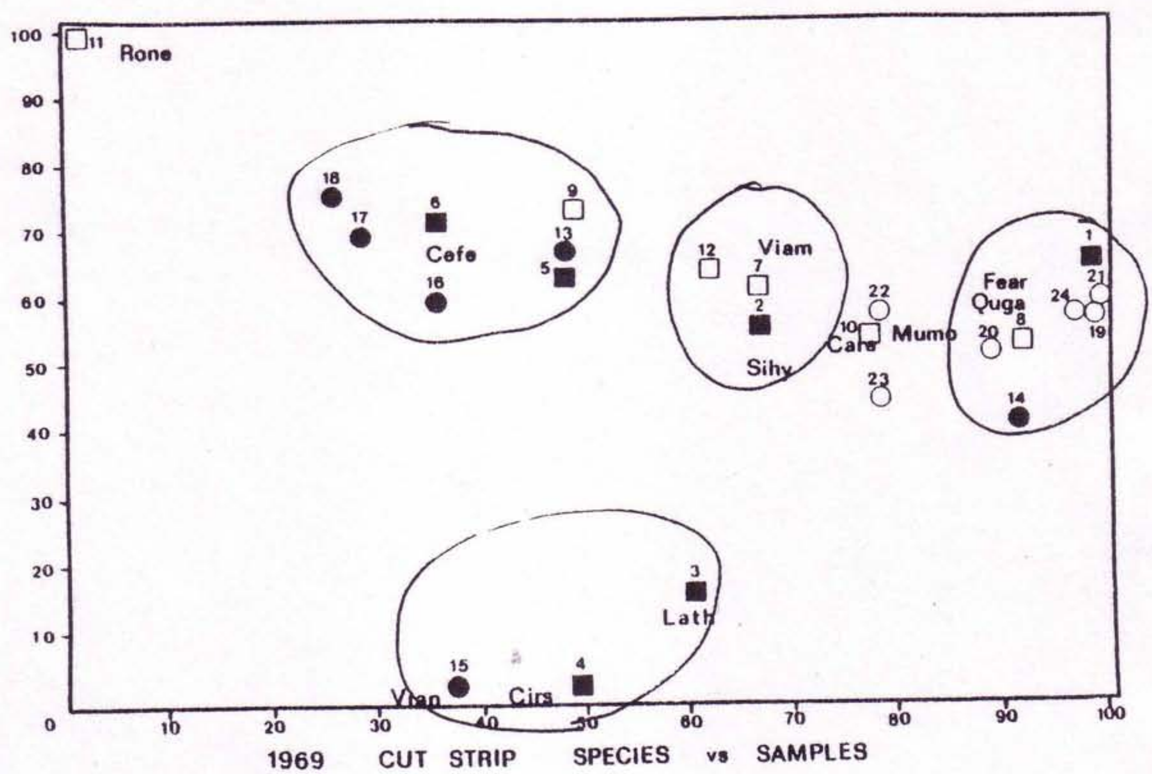


Fig. 3b

Figure 3.--1969 reciprocal averaging ordination of plant species vs. samples for (a) uncut, (b) cut strips. Proportion of total variance accounted for in first two axes is 36% and 29% respectively. Numbers refer to samples. Symbols: ■ = warm Siesta, □ = cool Siesta, ● = warm Brolliar, ○ = cool Brolliar.

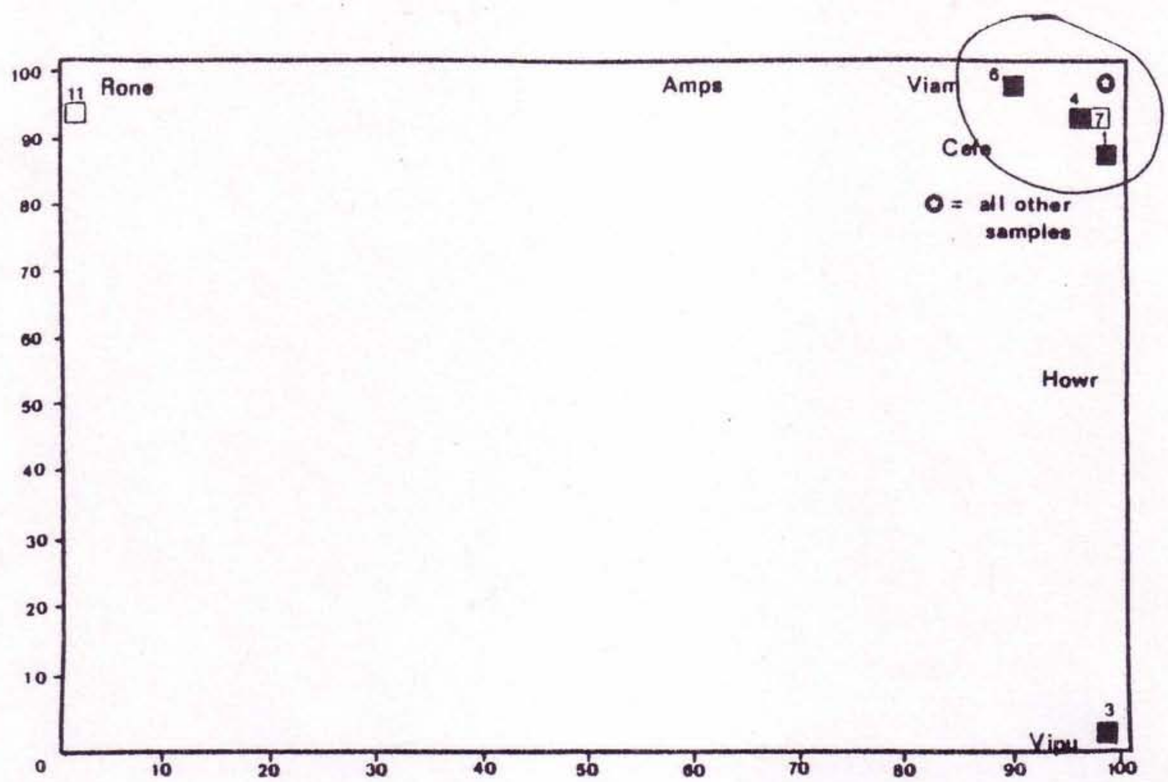


Fig. 3c

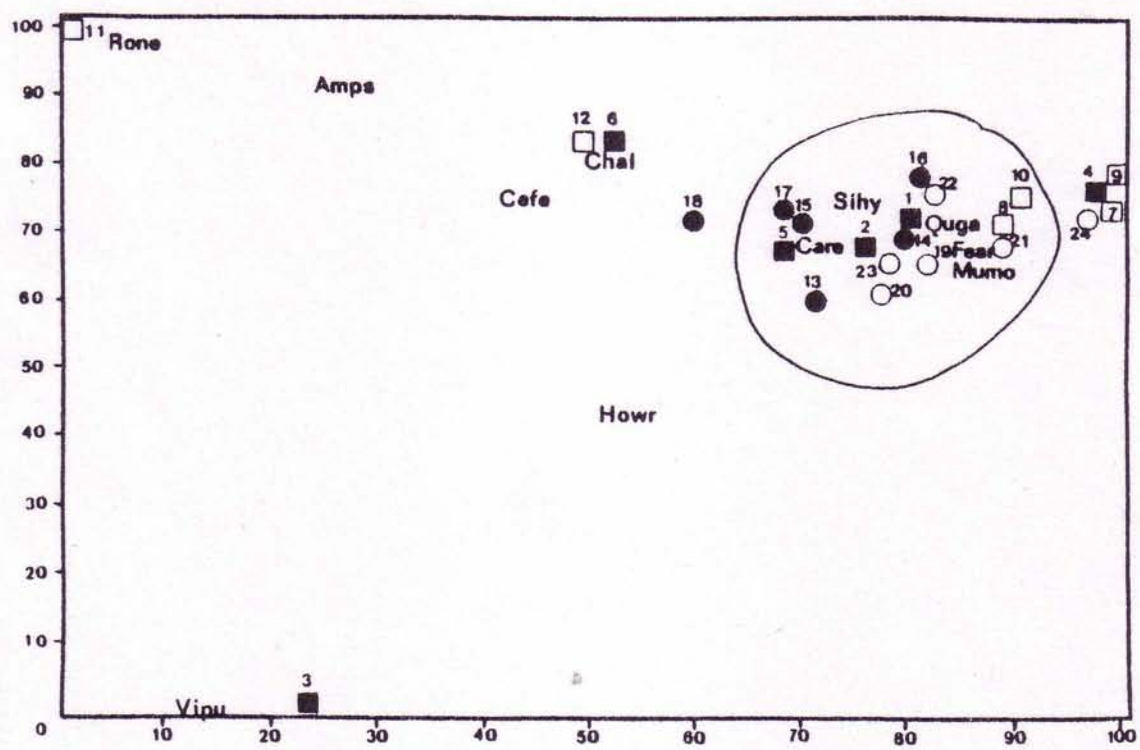
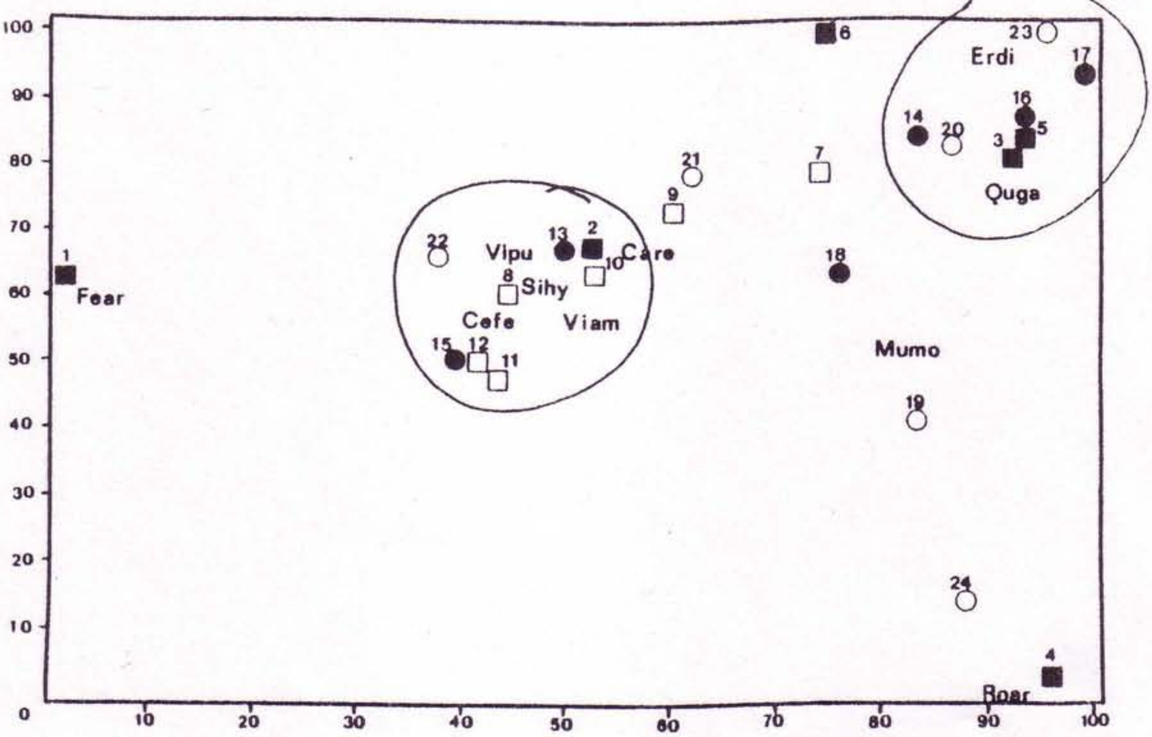


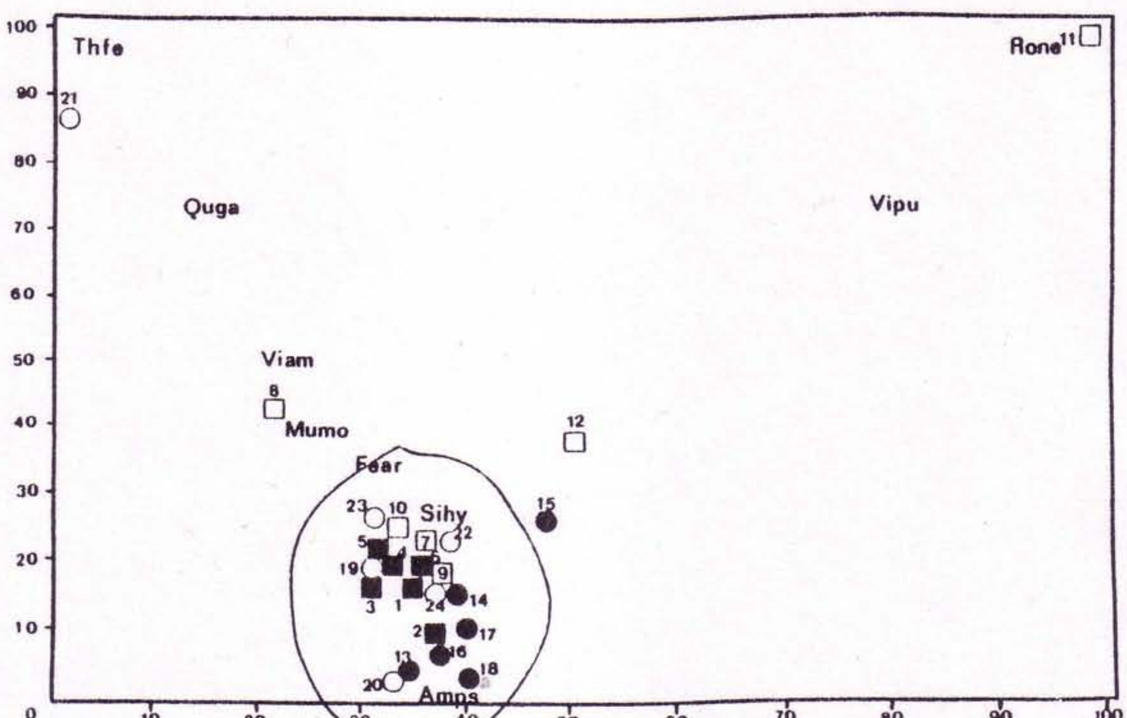
Fig. 3d

Figure 3.--Continued. 1970 reciprocal averaging ordination of plant species vs. samples for (c) uncut, (d) cut strips. Proportion of total variance accounted for in first two axes is 47% and 32%, respectively. Numbers and symbols as in Figure 3a,b.



1973 UNCUT STRIP SPECIES vs SAMPLES

Fig. 3e



1973 CUT STRIP SPECIES vs SAMPLES

Fig. 3f

Figure 3.--Continued. 1973 reciprocal averaging ordination of plant species vs. samples for (e) uncut, (f) cut strips. Proportion of total variance accounted for in first two axes is 43% and 30%, respectively. Numbers and symbols as in Figure 3a,b.

Perhaps most notable in these results are the outliers, which represent the most dissimilar samples (clusters). Note that in all the ordinations, except leave strip-1973, cluster 11 is an outlier (Figure 2). Clusters 1, 4, 6, and 12 often were either outliers or contained in an outlier group. Although they are individual samples, these outliers can be recognized as a group which, in addition to other recognized groups, reduces the overall data mass to distinct groups for interpretive results.

Figure 3 shows these outliers with species. Note that cluster 11 is associated with the shrub species Robinia neomexicana Gray (Rone).[4] This species was absent from leave strip-1973 sample. Other shrub species often associated with outliers are Quercus gambelii Nutt. (Quga) and Ceanothus fendleri Gray (Cefe). It is interesting to note that even though these shrubs often ordinate as outliers or in outlier groups, that the shrub class was shown to have a non-significant response to treatment. Some forbs often associated with outliers are Vicia pulchella H.B.K. (Vipu), Ambrosia psilostachya D.C. (Amps), Vicia americana Muhl (Viam), and Houstonia wrightii Gray (Howr). Individual grass species do not appear to have a consistent association with sample outliers.

To determine if the reciprocal averaging axes were related to site factors, correlation coefficients were calculated between sample locations on axes 1 and 2 and the values for aspect, slope, percent clay, percent gravel, soil depth, and total trees measured at each

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[4]Plant symbols are used to facilitate the comparison between the text and the figures. Species names were not included in the figure to avoid cluttering.

sample (Table 11). The best correlation was between axis 1 and slope in 1970 with R-value (correlation coefficient) equal to -0.6311. Most R-values indicated a poor correlation between the site values and reciprocal averaging axes. Although some significant correlations were found, the lack of consistent trends is important.

Table 11. Correlation coefficients (R-values) between reciprocal averaging axes and site factors

Axis	Year	Aspect	Slope	Clay	Gravel	Soil depth	Total trees
				R-values			
1	1969	-0.01	-0.391	-0.101	0.253	-0.020	0.306
	1970	0.117	-0.401	-0.052	-0.222	-0.121	0.240
	1973	0.100	-0.493*	0.228	-0.261	-0.263	-0.019
2	1969	-0.160	0.279	0.296	-0.073	-0.164	-0.153
	1970	0.021	-0.024	0.046	0.168	-0.158	0.138
	1973	0.268	0.010	-0.220	0.283	0.334	0.104
3	1969	0.103	0.309	0.017	0.064	-0.022	-0.213
	1970	0.004	0.106	-0.294	0.136	0.371	0.037
	1973	-0.290	0.522**	-0.040	0.159	0.306	-0.197
1	1969	-0.306	-0.273	-0.418	-0.258	0.262	0.294
	1970	-0.066	-0.631**	-0.148	-0.523**	-0.109	0.214
	1973	0.026	0.488*	0.371	0.379	-0.042	-0.319
2	1969	-0.218	0.171	-0.066	0.356	0.466*	-0.175
	1970	-0.074	0.194	0.088	0.323	-0.101	-0.107
	1973	-0.389	0.323	-0.319	-0.098	0.200	-0.053
3	1969	-0.252	-0.041	-0.436*	-0.280	0.379	0.257
	1970	0.015	0.064	-0.390	-0.006	0.056	0.543
	1973	-0.354	-0.272	0.089	-0.438*	0.023	-0.274

*Significant at 0.01 level

**Significant at 0.05 level

Chapter 6

DISCUSSION

Aboveground Understory Production

The yearly increase in herbaceous biomass production may be due to factors other than the treatment itself, or a combination of treatment effects and other factors.

The production of total, grasses, forbs, shrubs, and cool grasses increased proportionately from year to year, suggesting that factors which affected overall watershed productivity had similar effects on each plant group. This could mean that either: (1) the magnitude of increased understory production is such a strong influence that it obscures the differences in some of the position/site interactions, or (2) the differences which appear to occur within some plant classes could be the result of some other site factor(s). With respect to this study, and since soil, aspect, and soil-aspect interaction parameters showed no effect on plant group production, and since the differences are not consistent throughout, the former suggestion seems more likely. However, the evaluation of other site factors was beyond the scope of this research.

Herbaceous biomass production was significantly higher on the positions cleared of timber than on the uncut positions. This result is consistent with virtually all studies involving the removal of one-third or more of the ponderosa pine overstory (Clary 1975, Clary and Ffolliott 1966, Ffolliott and Clary 1974, Pearson and Jameson 1967).

In Oregon, McConnell and Smith (1965) showed similar increases in total, grass, and forb classes as were found in this study, including the lack of significant response in the shrub class. In South Dakota, Pase (1958) found significantly higher understory production under thinned stands than under unthinned stands of ponderosa pine. Although the timber removed on Watershed 9 was in alternating strips, the understory response is consistent with these other forest treatments in increased understory biomass productivity following treatment. These previous studies showed that understory biomass could reach 750-1500 lbs/ac following complete ponderosa pine removal. The cleared strips on Watershed 9 fall within that range, averaging 880 lbs/ac in the fourth year following treatment.

Although the uncut positions were not different within each sample year, they were different between years. Averaged together, all six positions had significantly increased from 52 lbs/ac in 1969 to 95 lbs/ac in 1970, and from 95 lbs/ac in 1970 to 126 lbs/ac in 1973. These values are consistent with studies involving uncut ponderosa pine forest stands (Clary and Ffolliott 1966) in Arizona.

A very definite edge effect existed at the interface of uncut forest and clearcut strip. On the cleared side of edges, understory production was greater than on the timbered side of edges. Understory production, for example, was 3.3 times higher on the cleared edge positions in 1969 than on the uncut edge positions. In 1970 production was twice as high on the cleared edge positions as on uncut positions and in 1973 it was 2.6 times as high. This suggests that the uncut edge positions were also responding to treatment but not to the degree of the cleared positions.

Figure 4 expresses the foregoing discussion graphically. Positions 1, 2, 3, 7, 8, and 9 were not found to be different when tested among themselves. The herbage production averages of these positions are well within the range of much documented research of uncut ponderosa pine forest (Clary 1975, Clary and Ffolliott 1966, Ffolliott and Clary 1974, Pearson and Jameson 1967). With the exception of shrubs, positions 4, 5, and 6 were always significantly greater than the uncut positions. Position 5 was depressed in 1969, probably due to the piling and burning of slash during treatment. By 1973, however, position 5 had far exceeded all other positions in herbage production. Actually, herbage production on position 5, the center-most position of the clearcut 60-foot-wide strip, is approaching herbage production levels documented by other research where the ponderosa pine overstory was removed (Clary 1975, Clary and Ffolliott 1966, Pearson and Jameson 1967).

This study suggests that increases in herbage production for the strip-cut watershed was due more to treatment than annual climatic changes. Although yearly climatic changes apparently played some role since production in the uncut positions all positions showed an increase, the increase was considerably smaller than in the cut positions.

Shiflet (1973) suggested that precipitation zones, topographical position, slope, aspect, and soils combine to create sites. In a previous study on the Beaver Creek Study Area, Clary et al. (1966) showed soil types and slope position to be important criteria for reducing sampling variance for herbage production. Since Watershed 9 was essentially in one precipitation zone (within a given year) and the sampling units were located similarly with respect to slope and

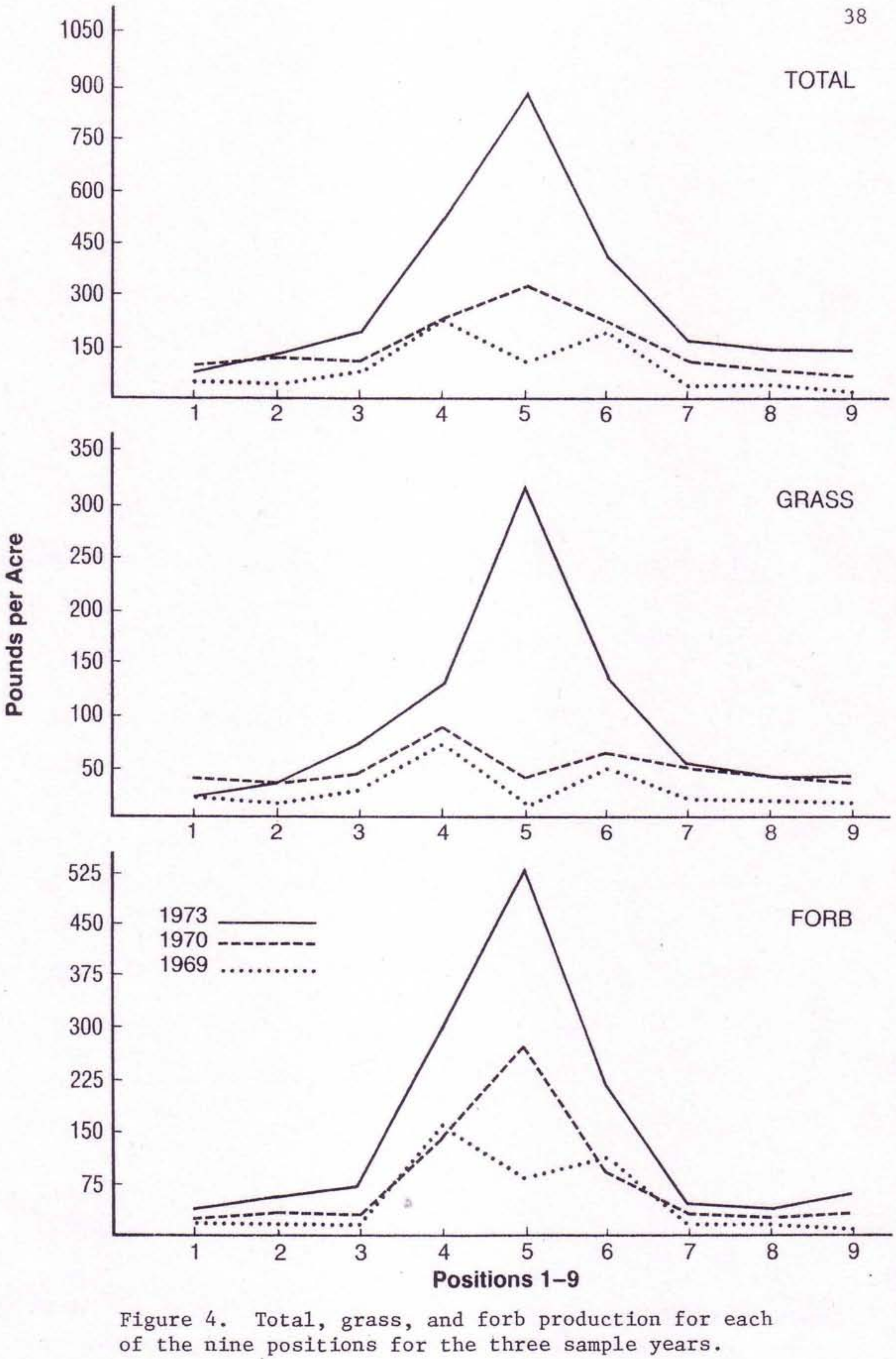

Figure 4. Total, grass, and forb production for each of the nine positions for the three sample years.

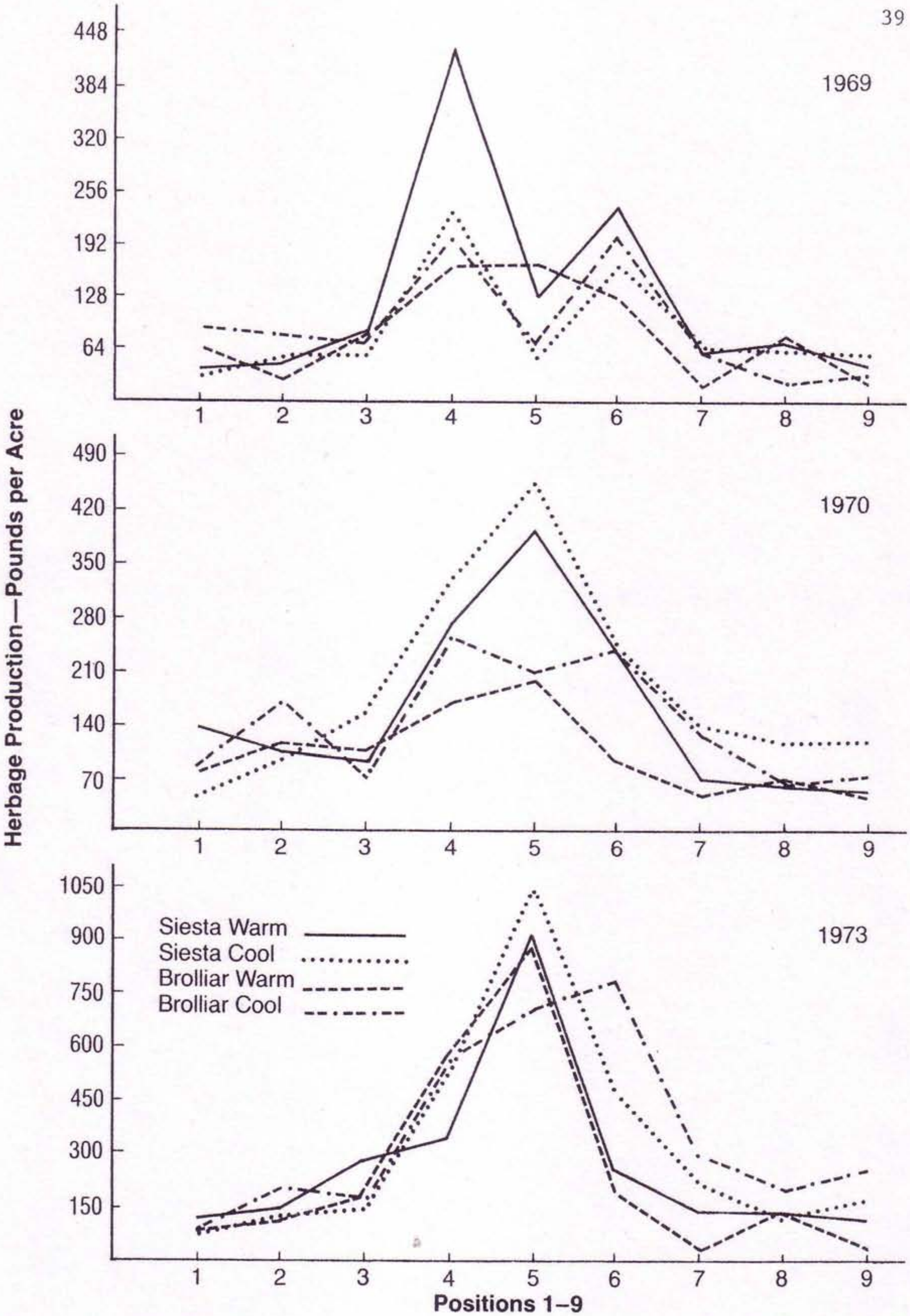

Figure 5. Herbage production for 1969, 1970, 1973 for each of the nine positions by soil and aspect strata.

topographic position, aspect and soils were the primary site factors analyzed in this study. Figure 5 represents the relationship of the four strata analyzed for each of the three sample years.

Analysis of variance showed soil, aspect, and their interaction to be non-significant factors affecting differences in the net biomass productivity of all plant groups, but some significant differences were found when these factors were analyzed including position as an interaction (Table 2). However, the lack of consistency between position and site factors confounds position/site effects. Evidently increased production within positions are of such magnitude that the variances are less in some interactions than others. Nevertheless, site factors appear to be influential in determining production levels, within some groups, when they interact with position.

While Clary et al. (1966) showed improved sampling precision could be gained by stratifying soil types and site factors, Ryan (1969, p. 33)[5] concluded in his report on the hydrologic and physical properties of some Beaver Creek soils that "stratifying by soil mapping units on a watershed would have no advantage over a simple random sample." The difference could be due to the quality of the soil mapping and the procedures utilized. Since this study utilized aerial photos in the selection of sample sites, stratification of site factors may not have been adequate for showing vegetation differences. Another possibility is that the soils were not sufficiently different to show a

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[5]Ryan, James Arthur. 1969. Sampling study of the physical properties of several soil types in northern Arizona. Page 33 In John L. Thomas, principal investigator. A study to determine the hydrologic and physical properties of some Beaver Creek soils. Final report. University of Arizona on file Flagstaff, Ariz.

difference in understory biomass compared to the influence of the treatment.

Prior to treatment, the watershed had a homogeneous canopy and the understory was fairly stable. The opening up of strips released the herbaceous species from canopy dominance regardless of aspect. Even after four years, the effect was similar on all aspects. The composition of species following treatment is probably related more to pretreatment composition than aspect, but this was not tested.

Finally soil, site, and aspect effects on herbage response may be too limited to detect effects, or the severity of the treatment may obscure soil and aspect effects.

Ordination Techniques

The reciprocal averaging ordinations showed some grouping of similar clusters, vegetation classes, and plant species (Figures 2 and 3). They also showed some relationships between cluster and vegetation classes on individual species (Figures 2 and 3). However, they did not show groupings of clusters corresponding to predetermined strata. This could have been due to inadequacies of the technique or to inadequacies of the strata (see previous discussion).

It is common ecological knowledge that plant communities differ over major environmental gradients, such as precipitation and elevational zones, and that site factors (e.g., extremely dry vs extremely wet sites) are important to specific plant communities. Ordination techniques across large environmental gradients have been fairly successful (Bray and Curtis 1957$, but ordination of sites within a small ecosystem has been less well documented. Huschle and Hironaka (1980) developed a conceptual model resulting from ordination techniques suggesting that ordination may be useful in describing changes in vegetation patterns following severe disturbances. However, in this particular situation, ordinations were of little value in detecting patterns in relation to site factors or disturbance. Perhaps the measured site factors were not as important to plant community response following a disturbance as other, less obvious factors. As more becomes known about plant community response mechanisms following a treatment, ordinations techniques may prove to be more useful, at the site level, in determining response patterns.

The results of this study suggest that ordination of data from a small ecosystem, following treatment, can show changes in plant group and plant species responses following a treatment. However, these changes may not always be interpretable. Either the environmental gradients examined in this study were not sufficiently different to show major vegetation patterns, or the severity of the treatment was great enough to obscure the effects of the site factors.

Treatment Effects on Livestock

Cattle are the primary livestock on Watershed 9 and perennial grasses are their primary forage. The increase in perennial forage grasses is essentially by the cool season species *Poa fendleriana* (Steud.) Vasey, *Sitanion hystrix* (Nutt.) J. G. Smith, and *Carex* spp. The higher productivity of these forage species in the center positions than in the uncut positions indicates that the treatment has increased forage availability for cattle.

The treatment did not appear to affect the cool season species to warm season species ratio. Apparently a lack in warm season grass production existed before treatment, perhaps due to past grazing history. Following treatment the cool season species were available to respond. Warm season species which appear to have increased on the cleared strips are Muhlenbergia montana (Nutt.) Hitchc. and Sporobolus interruptus Vasey.

These two warm season species, along with Poa fendleriana, Koleria cristata (L.) Pers., and Bromus spp., are important decreaser species which support the health of the range resource. Important decreaser forbs which also support a healthy range because of their forage value, nitrogen fixing ability, and/or soil stability properties are Lathyrus spp., Lotus wrightii Greene, Melilotus spp. and Vicia spp.

Since removing one-third of the overstory component would reasonably provide easier access, view, and handling of livestock, other range management objectives could benefit as well. Long straight strips (60 feet wide) supporting the forage, alternating with (120 foot wide) uncut strips, could be almost optimum for the livestock manager. Locating livestock during foraging times would be greatly enhanced. Movement of livestock along these corridors could ease distribution and enhance grazing management by herd manipulation.

Wildlife Implications Following Treatment

Elk and deer are the primary wildlife users of the same understory components as livestock. Elk primarily utilize grasses, while deer utilize forbs and shrubs.

The forb component was 480% higher on the cut strips than on the uncut strips following the treatment. Essentially all these forb species are forage species for deer in ponderosa pine communities (Neff

1980a). The most important species which showed the greatest response are Lactuca serriola L. and Lotus wrightii (Table 11). The increase in forage available for deer use, therefore, was significantly higher on the cut strips than on the uncut strips. The increase in perennial grass production, particularly in the cleared strips, greatly improves the availability of forage for elk.

Improving the forage for deer and elk does not necessarily improve the overall habitat. Some important specific wildlife sites were probably disturbed due to the rigidity of the treatment; however, Neff (1980b) concluded that no watershed treatments on the Beaver Creek Area adversely affected deer and elk habitat overall. Most research on overstory treatments in the ponderosa pine type (Pearson and Jameson 1967, Neff 1980b, Clary and Larson 1971) have shown increased deer use of treated areas. Reynolds (1966) and Patton (1969) have shown that deer prefer small openings, either cut or natural, in ponderosa pine. Edge effect was shown to be particularly important in these studies. This important edge effect was greatly increased due to the alternating of cut and leave strips. Dense stands of timbered strips maintained important hiding and thermal cover requirements for wildlife habit. Alternating these timber-related requirements with the improved forage resource probably improved habitat conditions or provided greater distribution and use by deer and elk over the entire large watershed.

Chapter 7

SUMMARY AND CONCLUSIONS

The first objective of this study was to evaluate the effects of the strip-cut treatment on the range resource values, i.e., net understory biomass productivity; livestock, deer, and elk forage production; and utilization patterns. I found:

1. Understory biomass production increased significantly between 1969 and 1970 by 36%. Understory biomass production increased significantly between 1970 and 1973 by 49%.
2. Understory biomass production was significantly greater on cut strips than on uncut strips by 69%, 61%, and 76% for each respective year, 1969, 1970, and 1973.
3. Yearly increases in cattle and elk forage (primarily grasses) and deer forage (primary forbs) were noted on the cleared strips but production on the uncut strips remained unchanged.
4. The shrub component was similar on both the cut and uncut strips.
5. Uniformity of treatment method over the 900 plus acre watershed could improve the distribution of wildlife utilization patterns over the treated area.

A second objective of the study was to determine the relationship of soils and other site factors to treatment effects on the understory plant community. Although it is generally believed that soil and aspect affect understory biomass productivity and composition, this study showed little difference in understory productivity and composition between different soils and aspects. This lack of difference could be caused by several factors. Methodologies used to randomly select sampling sites might not have been precise enough to detect differences between soils or between aspects. The yield responses of the two soils and two aspects studied were not significantly different under this type of treatment. Furthermore, the duration of this study may have been too limited to detect these soil and aspect affects. Finally, the severity of treatment may have obscured the soil and aspect effects.

The third objective of this study was to investigate the reciprocal averaging technique as a method for evaluating plant response to a strip-cut treatment. These results are summarized as follows:

1. The ordination suggested a relationship between certain plant species or classes and samples.
2. Ordination of samples with plant classes (total, grass, forb, shrub) had more interpretive value because of the consistency of the ordination grouping between years. Although ordination of samples with plant species also provided groupings of similar points, inconsistency between years made interpretation difficult.
3. Reciprocal averaging of data from different years following treatment showed changes in the relative ordination position of plant classes, species, and samples. However, the reasons for changes in position were not clear.

4. The predetermined site factors evaluated in this study could not be consistently associated with plant class or species response following treatment.

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APPENDIX

Scientific and Common Names and Symbols Used in the Text for Plants Found on Watershed 9

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Graminoids

Blepharoneuron tricholepis (Torr.) Nash	pine dropseed	Bltr
Bouteloua gracilis (H.B.K.) Lag.	blue grama	Bogr
Bromus spp.	brome	Brom
Carex spp.	sedge	Care
Festuca arizonica Vasey	Arizona fescue	Fear
Koleria cristata (L.) Pers.	junegrass	Koer
Muhlenbergia montana (Nutt.) Hitchc.	mountain muhly	Mumo
Poa fendleriana (Steud.) Vasey	muttongrass	Pofe
Sitanion hystrix (Nutt.) J.G. Smith	squirreltail	Sihy
Sporobolus interruptus Vasey	black dropseed	Spin

Forbs

Ambrosia psilostachya D.C.	ragweed	Amps
Epilobium paniculatum Nutt.	willow-weed	Eppa
Geranium fremontii Torr.	cranesbill	Gefr
Houstonia wrightii Gray	houstonia	Howr
Lactuca serriola L.	prickly lettuce	Lase
Lathyrus spp.	peavine	Lath
Lotus wrightii (Gray) Greene	deer-vetch	Lowr
Melilotus spp.	sweet clover	Meli
Thermopsis pinetorum Greene	golden-pea	Thpi
Vicia americana Muhl	vetch	Viam
Vicia pulchella H.B.K.	vetch	Vipu