MASTER

ECOCLIMATE STUDIES

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June, 1979

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PREPARED FOR THE UNITED STATES DEPARTMENT OF ENERGY

Under Cooperative Agreement #DE-FC20-78LC10787

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ACKNOWLEDGEMENT

The research discussed herein was conducted with the partial assistance of the United States Department of Energy under contract number ET-76-A-03-1787.

INTRODUCTION

Ecoclimatic studies on the Geokinetics Shale Group Field Research site -- section 2, T14S, R22E, Uintah County, Utah -- were initiated during April of 1978. Recording stations were established in each of the four major vegetation types on the LOFRECO site for the purpose of obtaining climatic data from the environmental zone that has the greatest influence on plant distributions and growth. This zone is known as the boundary layer, micro-environment, or ecoclimate of a site.

The data presented are those obtained from the period beginning in late April of 1978 and extending through early November of the same year. Ecoclimate studies will continue through the growing season of 1979.

OBJECTIVES

Ecoclimate studies have three primary objectives:

- (1) to define site specific environmental characteristics that affect herbaceous plant productivity and, subsequently the carrying capacity of the site;
- (2) to obtain environmental information that is directly applicable to planning and evaluating revegetation of disturbed sites; and
- (3) to obtain data that can be used in distinguishing between the effects of changes caused by development versus those that are the result of natural trends and cycles.

These objectives are addressed in this report to the extent possible at this juncture. Further contributions of the ecoclimate data in meeting the program objectives will be addressed in the final report.

EXPERIMENTAL DESIGN

Data Collection

Ecoclimatic data were obtained from eight locations on the LOFRECO site. Data stations were established in the eight permanent vegetation study plots. The stations were arranged in pairs; one pair in each of the paired vegetation plots, corresponding to control and treatment sites. The location of the ecoclimate recording stations and their corresponding vegetation plot and type are given on Figure 1, and are listed in Table 1.

Ecoclimatic parameters were recorded at hourly intervals during the growing season (April-May through October-November). Values measured were recorded on thermal paper tapes, and include the following

TABLE 1
 ECOCLIMATE STATION AND THEIR
 ASSOCIATED VEGETATION TYPES
 LOFRECO SITE

1978

Ecoclimate Station #	Vegetation Type	Plot #
E 01	South-facing Pinyon-Juniper Woodland	V10
E 02	North-facing Pinyon-Juniper Woodland	V20
E 03	Sagebrush-saltbush lowlands	V30
E 04	Sagebrush-grass uplands	V40
E 05	South-facing Pinyon-Juniper Woodland	V11
E 06	North-facing Pinyon-Juniper Woodland	V21
E 07	Sagebrush-saltbush lowlands	V31
E 08	Sagebrush-grass uplands	V41

FIGURE 1
VEGETATION STUDY PLOT LOCATIONS

SECTION 2, T14S, R22E, UTAH COUNTY, UTAH

parameters:

(1) station number and day of year (doy)	1100.# (1) (10 April)
(2) time of day	1000.# (10am)
(3) precipitation (accumulated through
9.99" and reset)	1.# (1/100th in.)
(4) ambient air temperature	170.+ (17.0°C)
(5) soil surface temperature	188.+ (18.8°C)
(6) battery voltage	130.+ (13.0v)
(7) spare channel	0.+
(8) end-of-run	0.T

Recording sensors were all located within the vegetation canopy. Ambient air temperature sensors were placed at a height of 1 meter in the woodland and sagebrush-saltbush sites and at a height of 0.5 meters in the sagebrush-grass sites. All soil surface temperature sensors were placed in the litter or soil surface. Precipitation sensors (tipping bucket type) extend to a height of approximately 0.75 meters.

Data Reduction

A hard copy of the raw data from each station was produced directly from the raw data tapes. This hard copy is a file of all values collected during the 1978 growing season.

Statistical Analysis

Reduced temperature data were subjected to four types of testing: (1) paired t-evaluation, (2) one-way analysis of variance, (3) regression analysis, and (4) multiple-range-test comparisons.

The statistical testing procedures were designed to evaluate the differences between temperatures in similar vegetation types during 1978. These data also form the basis for evaluating differences between any given station among years. Evaluation of means for any given station pair serves as a calibration tool for the first year of data collection. It provides a measure of similarity between different sites occupying the same vegetation type.

The hypotheses tested in the statistical evaluation are as follows:

$$H_0 : \bar{x}_1 = \bar{x}_5$$

where 1= station 1

5= station 5 (pinyon-juniper woodland, south-facing)

$$H_o : \bar{x}_2 = \bar{x}_6$$

where 2 = station 2

6 = station 6 (pinyon-juniper woodland, north-facing)

$$H_o : \bar{x}_1 = \bar{x}_5 = \bar{x}_2$$

$$H_o : \bar{x}_3 = \bar{x}_7$$

where 3 = station 3

7 = station 7 (sagebrush-saltbush lowlands)

$$H_o : \bar{x}_4 = \bar{x}_8$$

where 4 = station 4

8 = station 8 (sagebrush-grass uplands)

$$H_o : \bar{x}_3 = \bar{x}_7 = \bar{x}_4 = \bar{x}_8$$

Stations 1,5,2, and 6 were compared because of the similarity in the physical structure of these four woodland types. Conversely, station pairs 3 and 7; 4 and 8 display no apparent similarities that justified their comparison. The rationale behind defining sites as discrete units relates not only to the structural appearance of a site, but also to site features that are germane to reclamation tasks. Despite differences in aspect, pinyon-juniper sites are considered to present similar characteristics during revegetation, whereas sagebrush uplands and lowlands are considered to be significantly different in this respect.

Precipitation data have not been statistically evaluated. Precipitation does not lend itself to parametric testing and is further considered to be well-suited to graphic evaluation and comparison of total values by direct visual methods.

METHODS

Data collection

The eight 'eco-log' stations were manufactured by Wright Associates Inc. Longmont, Colorado. Electronics and the printing device are housed in a 30 x 30 x 15 cm Hoffman environmental enclosure mounted on a fixed plate angled 22° and positioned in a south-westerly direction. The station is powered by a 15 volt gel-cell battery continuously charged by a solar panel mounted on the lid of the environmental enclosure. Temperature sensors are Yellowsprings Instrument Company stainless steel-type

The precipitation collectors are Meteorological Research Institute tipping buckets.

Data Reduction

The hard copy produced from the raw data was used to perform a first-level statistical reduction of the data. During this procedure n-values, means, standard deviation, and standard errors were generated for temperature parameters. Precipitation data were summarized arithmetically.

First-level statistics were developed for the following data partitions:

- (1) daily mean temperature;
- (2) daily minimum temperature;
- (3) daily maximum temperature;
- (4) mean, mean minimum, and mean maximum temperature for (approximate) 10 day periods, monthly periods, and the entire season;
- (5) daily precipitation totals;
- (6) total precipitation on a ten day period basis, monthly basis, and for the entire season.

Statistical Analysis

T-Evaluation: Paired t-tests were performed on ambient air and surface temperature data. Two procedures were employed in this testing: (1) evaluation of station pairs using daily means on a ten day period basis, and (2) evaluation of station pairs using period values on a seasonal basis. The null hypothesis discussed above were accepted if: $0.025 \leq p(t) \leq 0.975$.

Analysis of Variance: One-way analysis of variance tests were conducted on air and soil surface data on a period and seasonal basis. The hypotheses tested discussed above were accepted if: $0.025 \leq Q(f) \leq 0.975$.

Regression Analysis: Station pair temperature values were regressed on each other in order to determine correlation coefficients for each pair: 1-5, 2-6, 3-7, 4-8, and 1-2. Regression analysis was based on seasonal data of the greatest duration of correspondence between x and y values.

Multiple Range Testing: Student-Newman-Keuls multiple range testing (SNK) was applied to temperature data using station groups: 1, 5, 2, and 6; 3, 7, 4, and 8. The SNK multiple range test was used to elucidate differences appearing in the t-test and analysis of variance procedures. As a result, the station groups were compared on the basis of air and soil temperature means and mean maximum values. All stations were compared on

the basis of soil temperature maximum values.

RESULTS AND DISCUSSION

Ecoclimate data obtained during the 1978 growing season are presented below (Tables 2 through 13). General descriptions of the ecoclimate of each vegetation type occurring on the study area are given in terms of temperature and moisture characteristics. Comparisons between station pairs and between selected non-station pairs are also presented.

General Characteristics

Ecoclimate is essentially controlled by the structural features residing in vegetation and soils. The most distinct controlling feature relating vegetation to ecoclimate is canopy cover. The vegetation canopy influences temperatures in both soils and air. The extent of the canopy also affects the amount of rainfall reaching the surface. Soil characteristics, particularly texture, affect available moisture. The sum of these effects are controls on light, evaporation, and soil moisture.

The influences created by vegetation and soils act within a zone known as the boundary layer. This is the zone between the uppermost extent of the vegetation canopy and the lower-most extent of soil. Within the boundary layer plant densities, vertical layering of vegetation growing at different heights, and life-form categories of plants are directly influenced by the ecoclimate.

The interaction between parameters in the ecoclimate are of high significance. Although vegetation structure contributes significantly to ecoclimate conditions, soil characteristics are important determinants to the types of plants that are capable of growing and reproducing in an area. The regional and local climatic conditions of a site contribute the basic ingredients that are acted upon by vegetation and soils. All of these contributions make up the ecoclimatic conditions that are unique to vegetation types and their associated soils.

On the LOFRECO site ecoclimates can be defined generally as partitions of the following controlling factors in order of their importance and site-specific influence:

- o a regional arid climate characterized by low precipitation

TABLE 2
ECO-CLIMATE PERIOD MEANS
1978
STATIONS 1 & 5
LOFRECO SITE
MEAN TEMPERATURE

PERIOD	STATION 1*		STATION 5+	
	AIR TEMPERATURE	SOIL TEMPERATURE	AIR TEMPERATURE	SOIL TEMPERATURE
May 1- 9	9.3 ± NA [#]	9.4 ± NA	9.0 ± NA	8.7 ± NA
10-19	14.8 ± 1.43	16.6 ± 1.11	14.4 ± 1.38	14.4 ± 1.36
20-31	13.2 ± 0.79	16.6 ± 0.64	12.9 ± 0.71	12.9 ± 0.95
1-31	13.6 ± 0.70	16.2 ± 0.65	13.3 ± 0.71	13.3 ± 0.79
June 1-10	15.2 ± 1.44	18.7 ± 1.42	12.4 ± 1.06	16.0 ± 1.30
11-20	19.8 ± 0.76	23.0 ± 0.62	19.9 ± 0.65	23.8 ± 0.26
21-30	21.4 ± 0.95	23.5 ± 1.14	21.4 ± 0.90	23.9 ± 1.18
1-30	19.0 ± 0.82	21.8 ± 0.79	18.9 ± 0.92	22.1 ± 0.93
July 1-10	21.8 ± 0.51	23.0 ± 0.77	21.5 ± 0.53	22.9 ± 0.64
11-20	23.4 ± 0.49	24.9 ± 0.64	23.0 ± 0.57	25.4 ± 0.66
21-31	23.4 ± 0.65	25.0 ± 0.30	22.9 ± NA	26.2 ± NA
1-31	22.8 ± 0.37	24.3 ± 0.40	22.3 ± 0.40	24.3 ± 0.53
August 1-10	22.9 ± 0.35	24.3 ± 0.36	23.2 ± 0.31	25.3 ± 0.57
11-20	17.5 ± 1.31	17.6 ± 1.15	14.4 ± 4.44	18.4 ± 0.88
21-31	21.3 ± 0.32	21.8 ± 0.37	20.5 ± 0.43	22.1 ± 0.34
1-31	20.5 ± 0.67	21.2 ± 0.72	21.2 ± 0.60	23.1 ± 0.63
September 1-10	21.3 ± 0.50	21.7 ± 0.49	21.6 ± 0.48	22.9 ± 0.40
11-20	13.8 ± 1.95	14.6 ± 0.94	14.5 ± 0.99	15.5 ± 0.61
21-30	15.6 ± 0.39	14.6 ± 0.56	15.5 ± 0.60	13.8 ± 0.62
1-30	17.8 ± 0.95	25.8 ± 1.28	16.8 ± 0.81	16.4 ± 1.05
October 1-10	12.4 ± 0.24	NO DATA	12.5 ± 0.91	10.7 ± 0.90
11-20	11.8 ± 0.71	10.6 ± 1.50	10.5 ± 1.10	9.9 ± 0.67
21-31	9.1 ± 0.85	6.9 ± 1.18	8.2 ± 1.79	6.2 ± 0.62
1-31	11.5 ± 0.46	8.4 ± 1.20	11.0 ± 0.76	9.5 ± 0.64
November 1- 5	NO DATA	NO DATA	7.6 ± 0.55	5.6 ± 0.56

± values are equal to the standard error of the mean

* Station 1 = Vegetation Plot 10, South-Facing Pinyon-Juniper Woodland

+ Station 5 = Vegetation Plot 11, South Facing Pinyon Juniper Woodland

± NA indicates that the number of observations making up the value were not sufficient to calculate the standard error

TABLE 3
ECO-CLIMATE PERIOD MEANS
1978
STATIONS 1 & 5
LOFRECO SITE
MEAN MINIMUM TEMPERATURE

PERIOD	STATION 1		STATION 5	
	AIR TEMPERATURE	SOIL TEMPERATURE	AIR TEMPERATURE	SOIL TEMPERATURE
May 1- 9	1.5 ± NA	2.5 ± NA	2.3 ± NA	3.6 ± NA
10-19	5.3 ± 1.14	3.9 ± 0.69	5.6 ± 1.30	5.5 ± 0.86
20-31	3.3 ± 1.05	2.6 ± 0.69	4.2 ± 0.94	6.0 ± 0.64
1-31	3.9 ± 0.76	3.1 ± 0.47	4.6 ± 0.74	5.7 ± 0.65
June 1-10	6.5 ± 1.32	5.4 ± 0.92	4.0 ± 0.74	7.9 ± 0.48
11-20	7.7 ± 0.89	6.9 ± 0.37	8.5 ± 0.97	11.6 ± 0.54
21-30	11.0 ± 1.14	11.1 ± 0.78	12.1 ± 1.02	13.7 ± 0.74
1-30	8.5 ± 0.77	7.9 ± 0.67	8.9 ± 0.90	11.4 ± 0.61
July 1-10	10.5 ± 0.94	10.7 ± 0.64	10.9 ± 1.01	12.3 ± 0.50
11-20	14.9 ± 0.71	15.0 ± 0.72	13.3 ± 1.11	15.0 ± 0.62
21-31	12.9 ± 0.98	13.4 ± 0.76	15.0 ± NA	14.6 ± NA
1-31	12.7 ± 0.60	13.0 ± 0.51	12.3 ± 0.76	13.8 ± 0.49
August 1-10	11.7 ± 0.78	12.1 ± 0.54	12.4 ± 1.05	11.2 ± 0.64
11-20	9.9 ± 1.68	10.1 ± 1.31	8.4 ± 2.01	9.9 ± 1.39
21-31	12.5 ± 0.92	12.4 ± 0.91	11.6 ± 0.94	11.8 ± 0.81
1-31	11.3 ± 0.70	11.5 ± 0.52	11.0 ± 0.77	11.5 ± 0.51
September 1-10	12.0 ± 0.88	12.1 ± 0.66	13.7 ± 0.86	13.6 ± 0.90
11-20	4.8 ± 1.59	6.8 ± 1.47	5.3 ± 1.23	6.1 ± 1.27
21-30	5.9 ± 0.55	5.7 ± 0.79	6.0 ± 0.78	5.8 ± 0.85
1-30	8.2 ± 0.95	8.9 ± 0.82	7.9 ± 1.05	8.4 ± 1.03
October 1-10	2.5 ± 0.32	NO DATA	4.2 ± 1.12	3.1 ± 0.93
11-20	4.6 ± 0.88	7.5 ± 1.41	4.4 ± 0.77	3.4 ± 1.11
21-31	3.0 ± 1.64	2.8 ± 1.64	3.2 ± 1.73	1.9 ± 0.85
1-31	3.6 ± 0.49	4.4 ± 1.45	4.1 ± 0.62	2.9 ± 0.58
Novemver 1- 5	NO DATA	NO DATA	0.9 ± 0.47	0.9 ± 0.60

TABLE 4
ECO-CLIMATE PERIOD MEANS
1978
STATIONS 1 & 5
LOFRECO SITE
MEAN MAXIMUM TEMPERATURE

PERIOD		STATION 1		STATION 5	
		AIR TEMPERATURE	SOIL TEMPERATURE	AIR TEMPERATURE	SOIL TEMPERATURE
May	1- 9	13.5 ± 1.48	21.5 ± 2.03	12.2 ± 1.74	19.0 ± 2.35
	10-19	23.2 ± 1.75	39.4 ± 2.73	22.4 ± 2.01	34.2 ± 3.37
	20-31	24.2 ± 0.72	41.8 ± 1.92	23.0 ± 0.74	28.9 ± 2.36
	1-31	20.7 ± 1.12	35.3 ± 1.12	19.8 ± 1.23	28.0 ± 1.92
June	1-10	27.3 ± 1.36	44.2 ± 2.32	25.6 ± 2.01	35.7 ± 3.63
	11-20	31.7 ± 0.77	27.0 ± 1.98	30.8 ± 0.38	45.8 ± 1.21
	21-30	32.9 ± 1.14	40.8 ± 2.20	31.4 ± 1.21	42.3 ± 3.05
	1-31	30.6 ± 0.79	43.9 ± 1.32	29.8 ± 0.85	41.8 ± 1.74
July	1-10	33.6 ± 0.54	38.6 ± 1.40	32.5 ± 0.38	42.1 ± 1.59
	11-20	34.1 ± 1.25	39.9 ± 1.40	33.1 ± 1.31	47.6 ± 2.47
	21-31	35.8 ± 0.83	41.2 ± 1.05	35.5 ± NA	55.1 ± NA
	1-31	34.6 ± 0.53	39.9 ± 0.71	32.6 ± 0.74	46.0 ± 1.58
August	1-10	35.8 ± 0.53	42.3 ± 0.91	35.4 ± 0.80	56.4 ± 2.81
	11-20	28.4 ± 1.45	30.5 ± 1.98	27.3 ± 1.84	39.4 ± 2.00
	21-31	30.9 ± 0.28	34.3 ± 0.94	30.7 ± 0.59	46.0 ± 1.97
	1-31	31.7 ± 0.82	35.8 ± 1.26	32.2 ± 0.80	49.4 ± 1.96
September	1-10	31.6 ± 0.66	35.4 ± 0.73	31.9 ± 1.09	45.1 ± 2.01
	11-20	19.5 ± 1.84	25.1 ± 1.88	22.8 ± 1.08	37.5 ± 0.83
	21-30	26.7 ± 1.20	28.9 ± 0.91	26.1 ± 0.79	33.1 ± 1.11
	1-30	25.8 ± 1.28	29.9 ± 1.16	26.8 ± 0.92	37.2 ± 1.34
October	1-10	24.6 ± 0.60	NO DATA	23.1 ± 0.66	33.3 ± 0.43
	11-20	20.8 ± 1.21	16.3 ± 1.17	18.3 ± 1.74	25.3 ± 3.05
	21-31	14.0 ± 1.41	10.4 ± 0.64	12.8 ± 1.36	13.8 ± 0.99
	1-31	19.1 ± 1.09	12.0 ± 0.88	17.9 ± 1.11	23.7 ± 1.87
November	1-10	16.0 ± 1.67	9.8 ± 0.85	15.6 ± 1.15	16.3 ± 1.29

TABLE 5
ECO-CLIMATE PERIOD MEANS
1978
STATIONS 2 & 6
LOFRECO SITE
MEAN TEMPERATURE

PERIOD	STATION 2 [*]		STATION 6 ⁺	
	AIR TEMPERATURE	SOIL TEMPERATURE	AIR TEMPERATURE	SOIL TEMPERATURE
May 1-9	8.8 ± NA	9.2 ± NA	NO DATA	NO DATA
10-19	12.5 ± 1.79	13.8 ± 0.92	10.4 ± NA	12.7 ± 0.81
20-31	12.8 ± 0.69	15.5 ± 0.52	NO DATA	14.3 ± 0.52
1-31	12.4 ± 0.83	14.4 ± 0.58	NO DATA	13.7 ± 0.48
June 1-10	15.1 ± 1.42	15.4 ± 1.28	NO DATA	13.7 ± 1.52
11-20	18.2 ± 0.69	21.4 ± 0.35	NO DATA	21.2 ± 0.50
21-30	20.5 ± 0.90	22.9 ± 0.81	NO DATA	21.6 ± 1.19
1-30	18.0 ± 0.74	19.9 ± 0.83	NO DATA	19.9 ± 0.90
July 1-10	21.7 ± 0.27	21.4 ± 1.13	NO DATA	22.0 ± 1.24
11-20	22.9 ± 0.35	24.0 ± 0.39	NO DATA	25.0 ± 0.44
21-31	20.9 ± 0.87	23.7 ± 0.36	NO DATA	23.4 ± 2.93
1-31	22.1 ± 0.32	23.2 ± 0.44	NO DATA	24.5 ± 0.61
August 1-10	21.9 ± 0.39	25.0 ± 1.82	NO DATA	25.4 ± 0.35
11-20	17.0 ± 1.43	18.7 ± 1.04	NO DATA	17.9 ± 1.29
21-31	19.0 ± 0.55	21.0 ± 0.18	NO DATA	21.1 ± 0.33
1-31	19.4 ± 0.60	21.6 ± 0.57	NO DATA	20.5 ± 1.13
September 1-11	18.8 ± 1.03	21.2 ± 0.54	NO DATA	21.7 ± 0.55
12-21	NO DATA	NO DATA	NO DATA	15.9 ± 0.62
22-30	13.9 ± 0.55	14.7 ± 0.38	NO DATA	17.0 ± 0.65
1-30	16.6 ± 0.85	18.3 ± 0.86	NO DATA	18.3 ± 0.63
October 1-10	11.5 ± 0.87	12.2 ± 0.60	NO DATA	14.3 ± NA
11-20	11.0 ± 0.33	11.1 ± 0.74	NO DATA	NO DATA

* Station 2 = Vegetation Plot 20, North-Facing Pinyon-Juniper Woodland

+ Station 6 = Vegetation Plot 21, North-Facing Pinyon-Juniper Woodland

TABLE 6
ECO-CLIMATE PERIOD MEANS
1978
STATIONS 2 & 6
LOFRECO SITE
MEAN MINIMUM TEMPERATURE

PERIOD	STATION 2		STATION 6	
	AIR TEMPERATURE	SOIL TEMPERATURE	AIR TEMPERATURE	SOIL TEMPERATURE
May 1- 9	0.6 ± NA	5.7 ± NA	NO DATA	NO DATA
10-19	3.5 ± 0.97	8.8 ± 0.66	0.6 ± NA	4.1 ± 1.28
20-31	2.7 ± 0.91	9.2 ± 0.31	NO DATA	5.0 ± 0.32
1-31	3.1 ± 0.58	8.8 ± 0.36	NO DATA	4.9 ± 0.39
June 1-10	5.0 ± 1.32	10.9 ± 0.58	NO DATA	6.9 ± 0.80
11-20	4.8 ± 0.76	13.7 ± 0.26	NO DATA	10.3 ± 0.63
21-30	9.1 ± 1.18	16.1 ± 0.49	NO DATA	12.6 ± 0.83
1-30	6.4 ± 0.75	13.7 ± 0.50	NO DATA	9.9 ± 0.64
July 1-10	9.8 ± 0.40	15.2 ± 0.74	NO DATA	12.8 ± 1.01
11-20	12.6 ± 0.83	17.9 ± 0.40	NO DATA	14.9 ± 0.51
21-31	9.5 ± 1.64	17.5 ± 0.70	NO DATA	14.7 ± 0.83
1-31	11.1 ± 0.63	17.0 ± 0.41	NO DATA	14.2 ± 0.46
August 1-10	10.2 ± 0.80	17.1 ± 0.31	NO DATA	14.1 ± 0.55
11-20	8.2 ± 1.56	14.3 ± 1.13	NO DATA	11.1 ± 1.55
21-31	9.4 ± 1.15	15.1 ± 0.41	NO DATA	12.6 ± 0.65
1-31	9.4 ± 0.68	15.7 ± 0.45	NO DATA	12.7 ± 0.58
September 1-11	9.9 ± 0.85	15.9 ± 0.43	NO DATA	13.6 ± 0.64
12-21	NO DATA	NO DATA	NO DATA	7.0 ± 1.24
22-30	3.5 ± 0.50	9.6 ± 0.48	NO DATA	7.3 ± 0.77
1-30	7.2 ± 0.91	13.3 ± 0.80	NO DATA	9.3 ± 0.80
October 1-10	11.5 ± 0.99	7.3 ± 0.58	NO DATA	9.9 ± NA
11-20	2.9 ± 1.47	7.2 ± 0.60	NO DATA	NO DATA

TABLE 7
ECO-CLIMATE PERIOD MEANS
1978
STATIONS 2 & 6
LOFRECO SITE
MEAN MAXIMUM TEMPERATURE

PERIOD	STATION 2		STATION 6	
	AIR TEMPERATURE	SOIL TEMPERATURE	AIR TEMPERATURE	SOIL TEMPERATURE
May 1- 9	11.4 ± 2.09	13.6 ± 1.14	NO DATA	NO DATA
10-19	21.7 ± 2.00	24.9 ± 1.96	21.0 ± NA	31.3 ± 4.85
20-31	23.1 ± 0.68	28.3 ± 1.21	NO DATA	39.1 ± 2.14
1-31	19.8 ± 1.15	23.3 ± 1.40	NO DATA	36.1 ± 2.42
June 1-10	25.9 ± 1.42	27.0 ± 1.49	NO DATA	34.6 ± 5.34
11-20	29.7 ± 0.66	37.2 ± 0.87	NO DATA	43.9 ± 0.91
21-30	31.2 ± 0.99	36.4 ± 1.87	NO DATA	38.9 ± 3.11
1-30	28.9 ± 0.74	33.4 ± 1.22	NO DATA	39.8 ± 1.85
July 1-10	32.6 ± 0.44	33.9 ± 2.24	NO DATA	43.5 ± 3.59
11-20	33.6 ± 0.92	36.0 ± 1.40	NO DATA	49.3 ± 2.60
21-31	32.4 ± 1.04	37.0 ± 2.03	NO DATA	54.1 ± 2.45
1-31	33.0 ± 0.50	35.6 ± 1.04	NO DATA	49.0 ± 1.83
August 1-10	34.8 ± 0.48	39.1 ± 0.32	NO DATA	55.3 ± 0.53
11-20	26.1 ± 1.63	27.6 ± 1.40	NO DATA	35.4 ± 2.24
21-31	29.8 ± 0.51	32.8 ± 0.86	NO DATA	41.3 ± 1.45
1-31	30.4 ± 0.83	33.3 ± 1.00	NO DATA	44.5 ± 1.74
September 1-11	28.7 ± 1.46	32.3 ± 0.68	NO DATA	42.5 ± 1.89
12-21	17.2 ± NA	26.3 ± NA	NO DATA	37.0 ± 2.45
22-30	25.9 ± 0.69	24.5 ± 0.49	NO DATA	36.9 ± 1.37
1-30	26.6 ± 0.97	28.7 ± 0.90	NO DATA	38.9 ± 1.15
October 1-10	23.3 ± 0.71	21.8 ± 0.38	NO DATA	37.8 ± 2.59
11-20	21.5 ± 1.14	18.2 ± 0.69	NO DATA	NO DATA

TABLE 8
ECO-CLIMATE PERIOD MEANS
1978
STATIONS 3 & 7
LOFRECO SITE
MEAN TEMPERATURE

PERIOD	STATION 3 *		STATION 7 +	
	AIR TEMPERATURE	SOIL TEMPERATURE	AIR TEMPERATURE	SOIL TEMPERATURE
April 28-30	NO DATA	NO DATA	NO DATA	NO DATA
May 1- 9	9.0 ± NA	10.8 ± NA	NO DATA	NO DATA
10-20	13.5 ± 1.16	15.7 ± 1.39	NO DATA	NO DATA
21-31	10.2 ± NA	11.6 ± NA	13.5 ± 0.95	12.0 ± 0.77
1-22	NO DATA	NO DATA	NO DATA	NO DATA
June 17-21	18.4 ± NA	24.0 ± NA	12.5 ± 1.16	12.8 ± 0.71
21-30	19.9 ± 1.13	23.7 ± 1.75	19.0 ± 0.77	20.7 ± 1.68
17-30	NO DATA	NO DATA	20.2 ± 0.95	20.6 ± 0.78
July 1-10	20.5 ± 0.30	23.3 ± 1.39	20.6 ± 0.50	20.3 ± 0.69
11-20	22.1 ± 0.39	25.7 ± 0.67	22.9 ± 0.34	22.8 ± 0.44
21-31	21.6 ± 0.64	27.1 ± 0.45	22.6 ± 0.85	23.8 ± 0.57
1-31	21.5 ± 0.31	24.8 ± 0.83	22.1 ± 0.38	22.4 ± 0.42
August 1-10	21.3 ± 0.46	25.7 ± 0.28	21.9 ± 0.44	23.8 ± 1.88
11-20	17.2 ± 1.53	18.4 ± 0.97	17.0 ± 1.39	18.2 ± 1.08
21-31	18.5 ± 0.62	20.9 ± 0.27	20.3 ± 0.22	22.0 ± 0.26
1-31	19.1 ± 0.58	21.9 ± 0.64	19.8 ± 0.65	20.6 ± 0.87
September 1-11	18.7 ± 0.85	20.8 ± 0.57	20.7 ± 0.66	22.6 ± 0.58
12-21	14.4 ± 0.43	16.4 ± 1.20	13.9 ± 0.71	17.6 ± 0.53
22-30	14.3 ± 0.54	16.0 ± 0.50	14.9 ± 0.48	18.1 ± 0.61
1-30	16.7 ± 0.68	18.6 ± 0.62	17.4 ± 0.80	20.3 ± 0.66
October 1-10	NO DATA	NO DATA	12.6 ± 0.73	16.1 ± 0.56
11-20	NO DATA	NO DATA	10.4 ± 1.52	11.5 ± 1.29
21-31	NO DATA	NO DATA	7.0 ± NA	8.9 ± NA
1-31	NO DATA	NO DATA	11.2 ± 0.75	13.6 ± 0.98
November 1- 7	NO DATA	NO DATA	8.2 ± NA	10.5 ± NA

* Station 3 = Vegetation Plot 30, Sagebrush-Saltbush Lowland

+ Station 7 = Vegetation Plot 31, Sagebrush-Saltbush Lowland

TABLE 9
ECO-CLIMATE PERIOD MEANS
1978
STATIONS 3 & 7
LOFRECO SITE
MEAN MINIMUM TEMPERATURE

PERIOD	STATION 3		STATION 7	
	AIR TEMPERATURE	SOIL TEMPERATURE	AIR TEMPERATURE	SOIL TEMPERATURE
April 28-30	NO DATA	NO DATA	NO DATA	NO DATA
May 1- 9	1.2 ± NA	3.8 ± NA	NO DATA	NO DATA
10-20	2.2 ± 0.37	4.7 ± 0.59	NO DATA	NO DATA
21-31	3.9 ± NA	6.3 ± NA	3.6 ± 1.22	4.9 ± 1.11
1-22	NO DATA	NO DATA	NO DATA	NO DATA
June 17-21	1.4 ± NA	7.5 ± NA	4.3 ± 1.50	6.9 ± 0.82
21-30	7.1 ± 1.11	10.4 ± 0.72	2.8 ± 1.71	8.4 ± 0.91
17-30	NO DATA	NO DATA	7.8 ± 1.35	11.1 ± 0.77
July 1-10	5.9 ± 0.45	10.8 ± 0.60	7.2 ± 0.86	10.5 ± 0.48
11-20	10.1 ± 1.03	13.3 ± 0.68	10.4 ± 1.05	14.2 ± 0.55
21-31	8.6 ± 1.14	13.3 ± 0.73	9.7 ± 1.24	13.9 ± 0.72
1-31	8.6 ± 0.58	12.6 ± 0.44	9.2 ± 0.65	13.0 ± 0.46
August 1-10	8.8 ± 1.01	12.1 ± 0.61	9.0 ± 0.92	13.4 ± 0.51
11-20	7.2 ± 1.62	10.8 ± 1.01	7.1 ± 1.75	9.4 ± 1.05
21-31	7.8 ± 1.38	10.6 ± 0.85	10.2 ± 1.16	12.0 ± 0.73
1-31	8.0 ± 0.75	11.2 ± 0.48	8.7 ± 0.77	12.0 ± 0.58
September 1-11	7.4 ± 0.81	13.4 ± 2.60	9.5 ± 1.00	12.1 ± 0.63
12-21	4.7 ± 2.43	8.2 ± 1.79	3.6 ± 1.77	7.7 ± 1.28
22-30	2.5 ± 0.63	6.0 ± 0.41	3.7 ± 0.49	6.6 ± 0.87
1-30	5.4 ± 0.73	10.2 ± 1.56	6.8 ± 0.97	9.8 ± 0.75
October 1-10	NO DATA	NO DATA	1.1 ± 0.37	4.8 ± 0.74
11-20	NO DATA	NO DATA	4.8 ± 0.58	6.5 ± 0.65
21-31	NO DATA	NO DATA	5.1 ± NA	7.4 ± NA
1-31	NO DATA	NO DATA	2.8 ± 0.65	5.1 ± 0.66
November 1- 7	NO DATA	NO DATA	-1.1 ± NA	2.7 ± NA

TABLE 10
ECO-CLIMATE PERIOD MEANS
1978
STATIONS 3 & 7
LOFRECO SITE
MEAN MAXIMUM TEMPERATURE

PERIOD	STATION 3		STATION 7	
	AIR TEMPERATURE	SOIL TEMPERATURE	AIR TEMPERATURE	SOIL TEMPERATURE
April 28-30	15.0 ± 2.31	20.7 ± 1.90	NO DATA	NO DATA
May 1- 9	14.2 ± 1.59	19.5 ± 1.47	NO DATA	NO DATA
10-20	23.5 ± 1.70	34.7 ± 2.76	NO DATA	NO DATA
21-31	19.2 ± NA	22.6 ± NA	24.7 ± 0.80	25.5 ± 1.70
1-22	NO DATA	NO DATA	NO DATA	NO DATA
June 17-21	30.9 ± 0.96	54.4 ± 0.65	28.5 ± 1.46	25.7 ± 1.50
21-30	32.4 ± 1.16	45.8 ± 4.18	32.1 ± 0.66	44.1 ± 2.69
17-30	NO DATA	NO DATA	33.0 ± 1.03	35.7 ± 1.81
July 1-10	33.5 ± 0.69	47.1 ± 2.52	34.7 ± 0.85	38.3 ± 2.30
11-20	35.6 ± 1.15	49.1 ± 3.10	36.4 ± 1.13	38.0 ± 1.67
21-31	36.0 ± 0.80	55.4 ± 1.14	37.8 ± 0.90	43.3 ± 0.82
1-31	32.0 ± 1.78	50.9 ± 1.46	36.3 ± 0.59	39.9 ± 1.04
August 1-10	36.4 ± 0.51	52.1 ± 1.82	38.1 ± 0.62	43.4 ± 0.70
11-20	27.9 ± 1.17	33.2 ± 1.68	29.1 ± 1.59	33.2 ± 2.18
21-31	31.5 ± 0.57	40.2 ± 1.76	32.4 ± 0.76	45.2 ± 2.28
1-31	31.9 ± 0.77	41.8 ± 1.71	33.2 ± 0.97	40.3 ± 1.43
September 1-11	30.4 ± 1.15	38.8 ± 1.54	32.5 ± 0.82	50.1 ± 1.31
12-21	19.8 ± 2.26	27.1 ± 4.01	24.7 ± 1.01	43.0 ± 1.33
22-30	29.0 ± 0.50	36.8 ± 0.85	29.4 ± 1.10	48.8 ± 1.09
1-30	26.7 ± 1.19	35.2 ± 1.29	29.3 ± 0.81	47.8 ± 0.90
October 1-10	26.0 ± 0.82	34.1 ± 0.44	26.8 ± 0.72	44.1 ± 1.11
11-20	22.0 ± 1.29	26.5 ± 2.30	22.9 ± 1.43	38.0 ± 3.51
21-31	17.5 ± 1.61	15.8 ± 0.84	14.8 ± 1.89	25.3 ± 3.28
1-31	22.0 ± 0.99	26.3 ± 1.75	21.7 ± 1.21	36.2 ± 2.14
November 1- 7	17.5 ± 0.96	11.0 ± 1.02	18.2 ± 0.90	30.1 ± 0.99

TABLE 11
ECO-CLIMATE PERIOD MEANS
1978
STATIONS 4* & 8+
LOFRECO SITE
MEAN TEMPERATURE

PERIOD	STATION 4		STATION 8	
	AIR TEMPERATURE	SOIL TEMPERATURE	AIR TEMPERATURE	SOIL TEMPERATURE
April 27-30	5.5 ± 0.73	8.6 ± 0.34	NO DATA	NO DATA
May 1-11	9.0 ± 1.68	10.1 ± 0.78	NO DATA	NO DATA
12-22	13.8 ± 1.31	15.0 ± 0.82	12.8 ± 0.65	15.8 ± 0.50
1-22	11.8 ± 1.21	13.0 ± 0.92	NO DATA	NO DATA
June 17-20	17.7 ± 0.77	22.2 ± 0.44	12.8 ± 0.72	17.8 ± 0.58
21-30	21.0 ± 0.88	23.5 ± 0.97	18.0 ± 0.91	23.6 ± 0.66
17-30	20.0 ± 0.77	23.1 ± 0.71	21.3 ± 0.89	25.0 ± 1.04
1-30	NO DATA	NO DATA	18.7 ± 0.98	23.1 ± 0.91
July 1-10	21.6 ± 0.63	22.5 ± 0.76	22.0 ± 0.42	24.5 ± 0.83
11-20	23.2 ± 0.50	24.5 ± 0.83	24.0 ± 0.34	26.5 ± 0.66
21-31	23.2 ± 0.63	27.2 ± 0.44	22.4 ± NA	24.3 ± NA
1-31	22.6 ± 0.38	24.8 ± 0.54	23.1 ± 0.33	25.5 ± 0.53
August 1-10	22.8 ± 0.44	27.1 ± 0.27	23.3 ± 0.47	27.0 ± 0.53
11-20	17.0 ± 1.80	18.3 ± 0.57	17.3 ± 1.27	18.5 ± 0.96
21-31	19.8 ± 0.46	22.2 ± 0.24	20.3 ± 0.47	21.8 ± 0.28
1-31	20.4 ± 0.59	23.4 ± 0.68	20.2 ± 0.66	22.3 ± 0.75
September 1-10	20.6 ± 1.10	23.1 ± 0.47	22.4 ± 0.39	23.5 ± 0.26
11-20	14.8 ± 0.85	17.7 ± 0.73	13.3 ± 1.81	16.2 ± 1.28
21-30	15.1 ± 0.63	18.6 ± 0.60	16.4 ± 0.53	17.3 ± 0.47
1-30	17.3 ± 0.72	20.3 ± 0.61	17.7 ± 0.97	19.2 ± 0.81
October 1-10	12.1 ± 0.75	16.3 ± 0.40	13.6 ± 0.52	14.3 ± 0.50
11-21	10.4 ± 0.76	13.5 ± 0.74	10.2 ± 1.20	10.5 ± 0.82
22-31	7.5 ± 1.36	8.3 ± 0.53	8.6 ± 1.88	6.1 ± 0.45
1-31	10.6 ± 0.58	13.7 ± 0.68	11.5 ± 0.72	11.5 ± 0.76
November 1-7	7.3 ± 0.67	8.7 ± 0.24	NO DATA	NO DATA

* Station 4 = Vegetation Plot 40, Sagebrush-Grass Upland
+ Station 8 = Vegetation Plot 41, Sagebrush-Grass Upland

TABLE 12
ECO-CLIMATE PERIOD MEANS
1978
STATIONS 4 & 8
LOFRECO SITE
MEAN MINIMUM TEMPERATURE

PERIOD	STATION 4		STATION 8	
	AIR TEMPERATURE	SOIL TEMPERATURE	AIR TEMPERATURE	SOIL TEMPERATURE
April 27-30	-0.6 ± 0.91	2.8 ± 0.41	NO DATA	NO DATA
May 1-11	1.5 ± 1.31	4.0 ± 0.78	NO DATA	NO DATA
12-22	3.9 ± 0.81	7.2 ± 0.75	2.1 ± 1.26	6.3 ± 0.35
1-22	3.4 ± 0.61	6.0 ± 0.69	NO DATA	NO DATA
June 17-20	3.6 ± 0.29	10.6 ± 0.36	2.6 ± 0.96	7.0 ± 0.91
21-30	9.6 ± 1.08	14.1 ± 0.70	2.2 ± 0.73	9.4 ± 0.57
17-30	7.9 ± 1.07	13.1 ± 0.66	10.2 ± 1.53	13.3 ± 0.71
1-30	NO DATA	NO DATA	6.5 ± 1.24	10.8 ± 0.78
July 1-10	8.7 ± 0.98	12.9 ± 0.69	10.4 ± 1.30	13.0 ± 0.82
11-20	12.7 ± 0.99	16.5 ± 0.69	12.3 ± 0.88	15.1 ± 0.40
21-31	11.6 ± 0.96	17.0 ± 0.61	12.7 ± NA	17.0 ± NA
1-31	10.9 ± 0.64	15.4 ± 0.52	11.4 ± 0.75	14.2 ± 0.49
August 1-10	11.0 ± 0.84	16.0 ± 0.47	12.3 ± 1.30	15.2 ± 0.54
11-20	6.8 ± 2.34	8.8 ± 1.99	7.6 ± 1.79	10.2 ± 0.99
21-31	10.3 ± 0.96	13.1 ± 0.58	10.5 ± 1.33	10.1 ± 1.27
1-31	9.6 ± 0.72	13.8 ± 0.53	10.1 ± 0.90	12.1 ± 0.65
September 1-10	11.1 ± 0.80	14.5 ± 0.51	12.6 ± 1.10	13.7 ± 0.55
11-20	4.7 ± 1.99	9.6 ± 1.39	4.3 ± 2.22	7.4 ± 1.55
21-30	4.6 ± 1.07	8.3 ± 0.85	4.9 ± 1.16	7.4 ± 0.54
1-30	7.3 ± 0.94	11.2 ± 0.76	7.7 ± 1.15	9.8 ± 0.82
October 1-10	2.5 ± 0.54	6.1 ± 0.50	2.6 ± 0.85	4.5 ± 0.50
11-21	2.8 ± 1.10	5.9 ± 0.56	3.1 ± 1.52	4.3 ± 1.07
22-31	-3.8 ± 1.82	2.2 ± 0.74	2.3 ± 2.35	1.3 ± 0.67
1-31	2.1 ± 0.63	5.8 ± 0.61	2.7 ± 0.74	3.9 ± 0.52
November 1-7	4.2 ± 0.88	2.7 ± 0.58	NO DATA	NO DATA

TABLE 13
ECO-CLIMATE PERIOD MEANS
1978
STATIONS 4 & 8
LOFRECO SITE
MEAN MAXIMUM TEMPERATURE

PERIOD	STATION 4		STATION 8	
	AIR TEMPERATURE	SOIL TEMPERATURE	AIR TEMPERATURE	SOIL TEMPERATURE
April 27-30	14.1 ± 0.99	19.7 ± 0.80	NO DATA	NO DATA
May 1-11	14.8 ± 1.88	18.5 ± 1.39	NO DATA	NO DATA
12-22	23.6 ± 1.44	27.6 ± 1.41	23.4 ± 0.89	31.8 ± 1.57
1-22	19.2 ± 1.53	23.0 ± 1.41	NO DATA	NO DATA
June 17-20	30.4 ± 1.50	40.9 ± 0.53	25.5 ± 1.00	37.3 ± 1.05
21-30	32.9 ± 1.12	37.7 ± 2.22	30.9 ± 1.05	46.5 ± 0.33
17-30	32.2 ± 0.93	36.7 ± 2.32	32.0 ± 0.95	43.4 ± 2.35
1-30	NO DATA	NO DATA	30.2 ± 0.86	42.7 ± 1.50
July 1-10	34.0 ± 0.70	37.3 ± 1.34	33.2 ± 0.73	43.3 ± 2.12
11-20	35.4 ± 1.04	38.4 ± 2.31	35.5 ± 0.74	44.5 ± 2.47
21-31	36.0 ± 0.86	44.7 ± 1.31	35.9 ± NA	51.3 ± NA
1-31	35.1 ± 0.50	40.5 ± 1.09	34.5 ± 0.52	43.8 ± 1.58
August 1-10	36.1 ± 0.68	46.1 ± 0.68	36.3 ± 0.71	49.8 ± 0.80
11-20	28.5 ± 1.63	30.7 ± 1.00	27.7 ± 1.26	32.3 ± 1.23
21-31	31.1 ± 0.49	36.1 ± 2.64	31.5 ± 0.63	31.7 ± 1.33
1-31	32.4 ± 0.75	38.6 ± 1.62	31.9 ± 0.83	41.3 ± 1.47
September 1-10	31.3 ± 0.72	37.3 ± 1.06	32.1 ± 0.72	39.9 ± 1.48
11-20	20.9 ± 2.28	30.7 ± 2.57	19.7 ± 2.15	29.6 ± 2.68
21-30	27.1 ± 0.96	38.5 ± 0.89	27.7 ± 1.00	36.9 ± 0.75
1-30	26.8 ± 1.09	35.9 ± 1.06	26.1 ± 1.30	35.2 ± 1.31
October 1-10	24.7 ± 0.77	37.3 ± 2.43	26.0 ± 0.50	34.3 ± 0.52
11-21	20.0 ± 1.60	28.1 ± 2.57	20.2 ± 1.57	22.1 ± 2.45
22-31	14.7 ± 1.64	17.6 ± 1.26	16.4 ± 1.43	13.2 ± 0.68
1-31	19.8 ± 1.08	26.7 ± 1.83	20.7 ± 1.12	23.9 ± 1.82
November 1-7	16.5 ± 1.13	21.0 ± 0.50	NO DATA	NO DATA

- (occurring principally as snow) and by high insolation;
- o distributions of two distinct soil regimes that influence the distribution and character of the vegetation, as a result of poor soil development and water availability on the one hand, and significant levels of toxic soil chemicals, on the other; and
 - o ensuing vegetational distributions that interact with climate and soils to produce distinct ecoclimates on the site.

In order to isolate the importance of the factors listed above on the ecoclimates on the LOFRECO site we can further partition the parameters as follows:

- o insolation appears to be the most significant single factor acting as a driving variable of the regional climate;
- o precipitation is an important factor also, but demonstrates some substantial local variations over the site;
- o soil type influences the availability of soil moisture, but is more directly important to vegetation distributions in terms of alluvial soils and residual soil categories and their associated soil chemistry regimes; and
- o vegetation canopy influences buffer the above effects: insolation is variously controlled by canopy types, as is precipitation and soil moisture.

The overall effect is an interface between temperature and moisture controlled by insolation at the ground surface and differentiated by canopy cover.

The discussion of each of the vegetation types in terms of ecoclimate illustrates the system of controls and their partitions in the manner in which ecoclimates are differentiated.

Temperature

Temperatures recorded at the soil surface show a general pattern of warming beginning in April and ending in late October. Mean temperatures are greatest in July in all sites (Figures 2 through 5).

Ambient air temperatures recorded at the maximum height of the canopy follow the same season pattern of soil surface temperatures, but attain higher values. There is some lag between soil temperatures and air temperatures. This is expected since soils warm more slowly

Figure 2

TEMPERATURE SUMMARY - LOFRECO SITE
SOUTH FACING PINYON-JUNIPER WOODLAND
(STATIONS 1 and 5)
1978

Figure 3
 TEMPERATURE SUMMARY - LOFRECO SITE
 NORTH FACING PINYON - JUNIPER WOODLAND
 (STATIONS 2 and 6)
 1978

Figure 4
 TEMPERATURE SUMMARY - LOFRECO SITE
 SAGEBRUSH-SALT BUSH LOWLANDS
 (STATIONS 3 and 7)
 1978

Figure 5
 TEMPERATURE SUMMARY - LOFRECO SITE
 SAGEBRUSH-GRASS UPLANDS
 (STATIONS 4 and 8)
 1978

and generally retain their heat for a longer period.

The average maximum soil surface temperatures reached during the growing season are 47°C in the south-facing pinyon-juniper woodland stands; 43°C in the north-facing woodlands; 50°C in sagebrush-saltbush lowlands; and 44°C in the sagebrush-grass uplands. (Tables 2 through 13)

Minimum temperatures for the vegetation types are 12°C, 13°C, 10°C, and 14°C, respectively.

Air temperature maximums are 33°C, 32°C, 34°C and 35°C, respectively. Air temperature minimums are 12°C, 9°C, 8°C, and 10°C, respectively (Tables 2 through 13).

Figure 6 illustrates the growing season pattern of air and soil temperature maximums and minimums. This figure shows that maximum soil temperatures are reached in sagebrush-saltbush lowlands. All other sites are similar in terms of this parameter. Maximum air temperatures vary little between sites. The most notable factor in both soil and air temperature maximums are apparent in the warming and cooling trends. The sagebrush-grass uplands warm earlier in the season than other sites; are sustained throughout the season, but do not have excessive values; and remain warm later in the season than other sites. This trend is controlled by the canopy cover through its effects on vertical mixing of air within the canopy, and is further contributed to by vegetation cover in the herbaceous layer.

The low stature of the shrub layer in the upland sites favors surface heating as soon as the seasonal climatic warming trend begins in the spring. The fine-textured soils and relatively high herbaceous cover add to the heat storage capacity in the upland sites, as well. Since these sites tend to receive more effective precipitation, both as snow and rain (also a result of the open canopy), the additional water retained in soils tends to dampen diurnal changes in soil surface temperatures. Vertical mixing of air within the boundary layer is also greatest in the upland sites. Well-developed mixing between soil and air allows the surface to cool along a steady gradient, thereby reducing overheating of the soil. The low stature of the vegetation also favors good lateral mixing: warm air at the top of the canopy and within the canopy is constantly circulated so that soil is not

Figure 6
MAXIMUM AND MINIMUM TEMPERATURES
ECOCLIMATE STATIONS - LOFRECO-1978

— Air Temperature
 — Soil Temperature
 - - - Extrapolated air
 - . - Extrapolated soil

reheated.

Sagebrush-saltbush lowlands, on the other hand, represent the opposite end of the scale of shrub canopy-induced effects on the ecoclimatic heat budget. The lowland sites have the most dense canopies of all vegetation types on the LOFRECO site. The relatively closed canopy of these sites retards heating of air within the canopy and of the soil surface during the beginning of the growing season. Temperatures eventually attained are chiefly the result of downward convection of heat accumulated at the surface of the canopy. Lateral air currents also bring in air warmed at other sites. Peaks in air and soil temperatures are created by warm air trapped in the canopy; a result of poor vertical mixing and retarded lateral air movement. Both of these effects are a result of high canopy cover and shrub density. Relatively rapid and early cooling are the combined result of canopy cover and cold air drainage. Cool air drains downward from up valley positions and valley sides to initiate cooling trends that are perpetuated by the canopy interception of insolation during the day-time hours.

Pinyon-juniper sites are on mid-scale relative to canopy effects on air and soil temperatures. Several important differences between the woodlands and the lowland sites occur. First, the canopy of the woodland sites is more open and higher than the lowland canopy. More vertical and lateral mixing occurs in the woodlands. Slow warming and early cooling in the woodlands is controlled by soil type, rather than strictly by insolation blocking. The coarse, light-colored soils have little heat storage, as well as relatively high reflectivity, as compared with other sites. The woodland soils are more rapidly cooled by the heat exchange occurring within the boundary layer.

South-facing woodland sites warm more rapidly than north-facing sites as a result of their predominant southerly exposure. For this reason the south-facing sites also reach higher maximum temperatures during the growing season. There is a greater degree of diurnal variation on the south-facing slopes, as well. Greater tree densities on the north-facing slopes dampen extreme heating and cooling trends, much like the lowlands, but to a lesser extent, because of the increased canopy cover.

The influences of canopy cover and soil type also represent feed-back mechanisms, as previously discussed. The greatest significance of feed-back are its effects on vegetation.

The soil characteristics that influence the nature of the shrub and herb layer of the upland sites participate directly in their perpetuation. The relatively mild soil environment characterized by fine-textured, relatively deep, and non-toxic soil nutrient regimes provide a medium that will support open shrub communities co-dominated by herbaceous plants. The relatively mild ecoclimatic conditions afforded by the plant structure and composition provide the longest growing season of the vegetation types occurring on the site. The least over-all environmental stresses due to limiting factors of high temperatures; extreme diurnal temperature change; and low effective precipitation and soil moisture availability occur in these upland sites.

In the lowland sites the more adverse soil characteristics have influenced the development of dense shrub stands. Sagebrush has attained greater densities and stature in the lowland sites. The high sagebrush densities are, in part, a result of decreased competition with herbaceous plants that are unable to tolerate the limiting soil environment. The dense canopy perpetuates many of these effects, as well as producing the limiting factors of higher soil moisture stress through high water demand, lowered effective surface precipitation, and reduced surface light.

Sites dominated by woodlands favor the tree species found, due to shallow, coarse-textured and well-drained residual soils. The woodlands are perpetuated on these sites because of lowered competition with herbaceous plants and shrubs. Germination and spread of shrubs and herbs is decreased under the environmental stress conditions of low available soil moisture and poor soil nutrient status. Soil moisture conditions are the combined result of well-drained soils, high insolation, and high surface evaporation. The pinyons and junipers that dominate the woodlands effectively avoid the stresses associated with these conditions because they rely on snow melt, water held in rock strata, and because of morphological adaptations that lower internal temperatures and water loss from tissues.

Precipitation

Rainfall recorded during the 1978 growing season is summarized in Figure 7 and Table 15. Total rainfall for the period of record (as recorded in the pinyon-juniper woodland sites) was 9.5cm. Precipitation was greatest in all sites during the months of May and June. November was the lowest precipitation month of record.

Winter precipitation contributes significantly to the growth of trees and shrubs in the intermountain region. Late spring and early summer rains are of great importance to the resumption of herbaceous growth.

Average precipitation values obtained from Bradley (1976) for this region is 24.2cm per year (3.8cm in spring, 5.1cm in summer, 5.1cm in fall, and 10.2cm in winter). The precipitation values obtained on the LOFRECO site during the summer season in 1978 are significantly lower at between 2.5cm and 4.5cm.

The differences in precipitation values recorded at the eight eco-log sites (Figure 7) reveals no definite pattern. Instead, there are evidences of local effects on precipitation, such as random movements of thunder storms across the site, variable wind directions associated with different storm events, and local differences in topography.

The only apparent trends are related to canopy and topography. The high values recorded at south-facing pinyon-juniper stands apparently relate to the interception of wind-borne precipitation by the canopy (Tueller and Clark 1975). The higher elevation of the south-facing sites also influences this phenomenon in comparison with the north-facing sites and lowland sites. Lowland sites are expected to show lower values also as a result of direct interception of rainfall by sagebrush leaves. The upland sites are subject to loss of recorded values due to wind blow-over. These effects are somewhat over-ridden by the lack of foliar interception.

South-facing pinyon-juniper woodlands received the greatest amount of rainfall during the 1978 growing season (9.5cm). Sagebrush uplands rank second in this order (8.0cm), followed by lowland sites

Figure 7

PRECIPITATION SUMMARY FOR THE ECO-LOG
STATION PAIRS - LOFRECO - 1978

TABLE 15
PRECIPITATION (cm) SUMMARY
1978
STATIONS 1-8 +
LOFRECO SITE

Month	Station Number							
	1	2	3	4	5	6	7	8
April	*	*	0.7	1.2	*	*	*	*
May	6.6	1.6	2.2	2.5	1.5	3.7	0.7	0.7
June	2.8	0.6	1.8	2.4	1.7	2.0	2.0	2.1
July	0.1	0.1	0.2	0.2	0.2	0.1	0.2	0.3
August	1.8	0.6	2.0	2.0	2.0	1.6	2.0	2.0
September	0.1	0.1	0.3	0.2	0.1	0.4	0.2	0.2
October	1.1	0.0	0.0	1.0	0.8	0.0	1.1	1.0
November	0.05	*	*	0.05	0.03	*	0.1	*
Total	12.6	3.0	7.2	9.7	6.3	7.8	6.3	6.3
Mean	1.8	0.5	1.0	1.2	0.9	1.3	0.9	1.1

* no data record

+ See Tables 2 through 13 for vegetation types
corresponding to station numbers.

(6.8cm) and north-facing pinyon-juniper woodlands (5.4cm). Although the variation in recorded precipitation makes it difficult to distinguish between local storm movement patterns and ecoclimatic effects, it is still possible to make statements regarding effective precipitation. Canopy cover is responsible for some of the low values recorded in the lowlands and north-facing woodlands. The intercepted moisture remains of importance to the vegetation of these sites, but is used by shrubs and trees to the significant exclusion of the herb layer. In upland sites the loss of recorded rainfall due to wind can be estimated at as much as 20 percent, so that as much as 9.6cm of rain may have been actually received. This moisture is also more effectively used by the herb layer, due to the sparse nature of the shrub layer. High values in the south-facing woodlands suggest less foliar interception, and, therefore direct use by trees. Rainfall received at the surface of the south-facing sites is highly subject to rapid loss by infiltration and evaporation. The latter feature is discussed below.

Available Moisture

In ecoclimatic terms, precipitation values are used to estimate the moisture input to the soil-vegetation system that predominates in interacting with ecoclimatic controls. The understanding of how this moisture is made available and used within the ecoclimate requires refinements of the moisture regime that precipitation contributes to.

Three basic properties are involved in defining the moisture budget of a given ecoclimate: 1) precipitation, 2) soil matric tension, and 3) surface evaporation potential. Precipitation has been previously discussed. Soil matric tension refers to the manner in which an individual soil holds moisture. The moisture in a soil that is available to absorption by plants is the difference between the ability of soil to maintain internal tensions that hold water (matric tension or suction) and the ability of plants to develop counter tensions in their root tissues. Soil water is traditionally assumed to be available to plants at soil tensions between -15 Bar (permanent wilting coefficient) and -0.33 Bar (field capacity) (Brady 1974). Theoretically, plants are unable to absorb water held in soils at tensions greater than -15 Bar. Studies of water potential conducted on arid environment vegetation

have shown that many of these plants can develop internal tissue pressures that are sufficient to absorb water held at pressures in the soil far in excess of -15 Bar. For examples Dina, et al (1973) report seasonal minimum water potentials for big sagebrush at -70 Bar Branson, et al (1976) report maximum seasonal values of -117 Bar for saltbush; corresponding soil tensions are shown at -85 Bar. Branson also reports maximum tensions for big sagebrush at -60 Bar, rabbitbrush at -40 Bar, and winter fat at -90 Bar. This information indicates that the major shrub species on the LOFRECO site are well-adapted to the soil moisture stresses reported below.

Figures 8 through 11 are soil moisture desorption curves constructed from soil analyses for the four major vegetation types on the LOFRECO site. The desorption or soil moisture curves are plotted from laboratory data against a logarithmic scale, using curve fitting. The curves represent an approximation of the behavior of soils under drying conditions. Using the precipitation records it is possible to estimate soil moisture tensions during the growing season. Estimates obtained in this manner show that the greatest moisture stresses occur in the south-facing sites are followed by north-facing woodlands in this respect. Lowland sagebrush sites show considerably lesser moisture stresses; upland sites have the least stresses.

Calculated values for available soil moisture revise this order somewhat (Table 16). Using the data tabulated on Table 16 the available water capacity was calculated for each soil that represents a distinct ecoclimate on the site. Values were determined using the data gathered from the soil moisture control section of each soil type. The soil moisture control section is roughly defined by soil texture: the finer the texture of predominant particles, the more shallow the control zone. The control section is used as a guideline for determining soil porosity as well as for determining the ability of a soil to develop high internal tension, and therefore retain water as unavailable to plants. Available water tends to increase as soil textures become finer. Sandy soils are generally lowest in available moisture; clays greatest (Brady 1974). The flow of water through soils (saturated and unsaturated) is also influenced by texture. More unsaturated flow occurs in fine textured soils, while more saturated flow occurs in coarse soils. This

Figure 8
 SOIL MOISTURE DESORPTION CURVE
 SOUTH FACING PINYON-JUNIPER WOODLANDS
 (LR LOAM)

Figure 9
 SOIL MOISTURE DESORPTION CURVE
 NORTH FACING PINYON-JUNIPER WOODLANDS
 (JR LOAM)

Figure 10
 SOIL MOISTURE DESORPTION CURVE
 SAGEBRUSH-SALTBUSH LOWLANDS
 (HAVRE LOAM)

Figure 11
 SOIL MOISTURE DESORPTION CURVE
 SAGEBRUSH - GRASS UPLANDS
 (LUHON LOAM)

TABLE 16
 AVAILABLE SOIL MOISTURE SUMMARY
 FOR THE FOUR SOIL TYPES
 CORRESPONDING TO ECOCLIMATE STATIONS
 1978
 LOFRECO SITE

Station #	Bulk Density (gm/cm ³)	% WHC ϵ 1/3 Bar (-)	% WHC -15 Bar	Sample (x) Thickness (cm)	% + AWC (=)	P.E. * cm/cm
1 & 5	1.41	26	13	25	4.6	5.1
2 & 6	1.40	26	14	46	7.7	5.1
3 & 7	1.48	24	13	112	18.2	5.7
4 & 8	1.48	24	13	58	9.4	6.3

@ See tables 2 through 13 for explanation

+ Percent Available Water Capacity

* Potential evaporation, cm H₂O / cm Soil (after Olgeirson 1977)

ϵ Percent water holding capacity

Soil Values from Neilson and Olgeirson

relates not only to moisture availability, but also to evaporative losses. Coarse soils tend to have higher conductivities and supply more moisture to plants and to evaporation. Evaporative losses can extend to depths up to 60cm. This type of loss is generally equal to 75 percent of the annual rainfall of an semiarid region, such as the LOFRECO site.

The available water capacity values (AWC) given in Table 16 must be adjusted for soil evaporative losses in order to be adequate indicators of moisture. Adjusting these values by using a ratio of potential evaporation to AWC gives a better indication of soil water status. For the bottomland sites this ratio equals 30% (Table 17) (5.7ml PE per day divided by an AWC of 18.2cm H₂O, times 100). In other words 30 percent of the available water capacity in the soil (in this case calculated to a depth of 112cm) is potentially lost to evaporation. The precipitation values for the lowland sites were recorded at total of 6.8cm for the summer season. Evaporative losses of this precipitation are equal to 30 percent or 2cm of moisture. In the sagebrush upland sites the ratio is equal to 70 percent, or 5.6cm. In woodland sites 70 percent, or 3.8cm of moisture are potentially lost to evaporation for north-facing sites, and up to 110 percent of the soil moisture can be lost to evaporation from south-facing woodlands. Potential evaporation values used were taken from Olgeirson (1977). It is important to note that these values are obtained from open soil surfaces and are significantly reduced by vegetation cover. The real value of the determination of potential evaporation relates to the moisture stresses that can develop in the different ecoclimates on the site. As such, this information imparts substantial elucidation of the causative relationships between plant growth and ecoclimatic parameters.

STATISTICAL COMPARISON BETWEEN STATION PAIRS & GROUPS

The seasonal tests performed on temperature data are discussed below. Period tests have been omitted because of the confusion they introduce. The results of the t-test evaluation of seasonal air and soil temperature values are given in Table 18. From the data in Table 18 it is apparent that no station pair is equal or different for all parameters tested. The absence of patterns in the testing data

TABLE 17
 POTENTIAL EVAPORATION SUMMARY
 (ADJUSTED FOR PERCENT AVAILABLE WATER CAPACITY)
 ECOCLIMATE STATIONS 1-8
 1978
 LOFRECO SITE

Station #		Potential Evaporation cm H ₂ O / cm soil	Percent Available(x) Water Capacity	Adjusted Potential Evaporation
1	5	5.1	4.6	110
2	6	5.1	7.7	70
3	7	5.7	18.2	30
4	8	6.3	9.4	70

TABLE 18
RESULTS OF t-TEST EVALUATION
USING AIR AND SOIL TEMPERATURE SEASONAL
VALUES FROM SELECTED ECOCLIMATE STATION PAIRS
1978
LOFRECO SITE

Station Pair	AIR TEMPERATURE			SOIL TEMPERATURE		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
1-5	1.92# 0.96+	-1.10 0.15	2.31 0.98	0.16 0.56	-1.21 0.13	-2.40 0.02
2-6	no data	no data	no data	1.19	<u>16.0</u> *	no data
3-7	-2.64 <u>0.01</u>	-2.46 <u>0.02</u>	-3.81 *	1.16 0.86	-0.62 0.27	0.19 0.57
4-8	-1.18 0.14	-2.41 <u>0.02</u>	1.03 0.83	-0.71 0.25	2.23 0.97	-3.16 *
1-2	<u>4.98</u> *	no data	<u>2.58</u> 0.99	<u>2.49</u> 0.16	no data	no data
5-6	no data	no data	no data	1.59 0.93	-0.75 0.24	0.37 0.64
1-6	no data	no data	no data	1.38 0.93	-5.16 <u>0.24</u>	-2.23 0.64
2-5	-1.16 0.13	-4.82 *	-0.32 0.38	-1.05 0.16	<u>11.34</u> *	-8.82 *

* t- value significant; p (t) not calculated

t- value

+ p (t)

underlined values indicated significant t-values,
null hypothesis rejected

The one-way analysis of variance testing was performed in order to compare station groups, these results are given in Table 19. The values in Table 19 are for station groups (i.e., 1,2,5,6- Woodlands; 3,4,7,8- sagebrush dominated sites). These tests illustrate essential equalities between station groups, except in the case of soil maximum temperature in group 1,2,5, (station 6 was not included because of the incomplete data record).

The final test performed on the data in an attempt to reduce confusion was a student- Newman-Kuels multiple range test. The results of this test, which compares all possible sets of means are given in Table 20. The parameters tested include only mean and maximum values; the minimum values were considered to be equal in the majority of cases (Q) (F) values, Table 19). The SNK test shows that all possible station pairs are equal statistically in terms of both air and soil temperature mean values. Maximum air temperature values are equal for tests performed on the woodland station pairs. Upland and bottomland sagebrush sites are significantly different in terms of air temperature maximum, excepting stations 7 and 8. Test performed on soil temperature maximums reveal that all station pairs are significantly different.

$H_0 : \bar{x}_1 = \bar{x}_5$, accepted for air and soil temperature means
 accepted for air and soil temperature minimums
 rejected for air and soil temperature maximums

$H_0 : \bar{x}_2 = \bar{x}_6$	no air temperature data
	accepted for soil temperature means
	rejected for soil temperature minimums
	no soil maximum temperature data

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TABLE 19
RESULTS OF ONE-WAY ANALYSIS OF VARIANCE
USING AIR AND SOIL TEMPERATURE SEASONAL
VALUES FROM ECOCLIMATE STATION GROUPS
AND SELECTED PAIRS

1978

LOFRECO SITE

Station Group or Pair	Air Temperature			Soil Temperature		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
1-5-2	0.13* 0.88#	1.03 0.37	0.17 0.85	0.12 0.95	3.23 0.30	<u>6.21</u> 0.01
3-7-4-8	0.28 0.84	1.74 0.18	0.37 0.78	0.35 0.79	1.24 0.31	1.06 0.38
1-5			NO TEST PERFORMED			2.30 0.14
5-6			NO TEST PERFORMED			0.23 0.64
1-6			NO TEST PERFORMED			4.42 0.05
1-2			NO TEST PERFORMED			3.34 0.79
2-6			NO TEST PERFORMED			<u>19.58</u> *

* f- value significant Q(F) not calculated

f- value

t Q(F)

underlined values indicate significant f-values;
null hypothesis rejected

TABLE 20
RESULTS OF STUDENT-NEWMAN-KUELS
MULTIPLE RANGE TESTING USING
AIR AND SOIL TEMPERATURE VALUES
FROM SELECTED STATION PAIRS
AND GROUPS.

1978

LOFRECO SITE

Station Pair or Group	Air Temperature		Soil Temperature	
	Mean	Maximum	Mean	Maximum
1-2	A	A	A	R
1-3				R
1-4				A
1-5	A	A	A	R
1-6				R
1-7				R
1-8				R
2-3				R
2-4				R
2-5	A	A	A	R
2-6				R
2-7				R
2-8				R
3-4	A	R	A	R
3-5				A
3-6				R
3-7	A	R	A	R
3-8	A	R	A	A
4-5				R
4-6				R
4-7	A	R	A	R
4-8	A	R	A	R
5-6				R
5-7				R
5-8				A
6-7				R
6-8				R
7-8				R

A = accept null hypothesis

R = reject null hypothesis

$H_0 : \bar{x}_3 = \bar{x}_7$	reject for air temperature mean, minimum, and maximum accept for soil temperature mean, minimum, and maximum
$H_0 : \bar{x}_4 = \bar{x}_8$	accept for air temperature mean and maximum reject for air temperature minimum accept for soil temperature mean and minimum reject for soil temperature maximum
$H_0 : \bar{x}_3 = \bar{x}_7 = \bar{x}_4 = \bar{x}_8$	accept for all parameters tested
$H_0 : \bar{x}_1 = \bar{x}_2$	reject for air temperature mean and maximum reject for soil temperature mean other parameters not tested, lacking data
$\bar{x}_5 = \bar{x}_6$	accept for soil parameters no air temperature data tested, lacking data
$\bar{x}_1 = \bar{x}_6$	accept for soil temperature mean and maximum reject for soil temperature minimum no air data tested, lacking data
$\bar{x}_2 = \bar{x}_5$	accept for air and soil temperature means accept for air and soil temperature maximum reject for air temperature minimum, soil temperature, minimum, and maximum

The regression analysis are given in Table 21. Those results are no more revealing of patterns in station similarities or differences than are the other statistical procedures that were applied.

CONCLUSIONS AND RECOMMENDATIONS

Evaluation of ecoclimatic data reveal the existence of four distinct ecoclimatic types that correspond with discrete soil and vegetation types on the LOFRECO site. The major controlling factor on ecoclimate is the structure of the vegetation, particularly the shrub or tree canopy of the various types.

Ecoclimatic conditions directly relate to the composition of all vegetation strata within the types and also relate significantly to the productivity of these types in terms of the herbaceous layer.

The information obtained is given priority in its usefulness to the reclamation of portions of the four ecoclimatic types that may be disturbed during the development of the LOFRECO site. These data reveal that the primary obstacle to any revegetation effort on the site will be the

TABLE 21
RESULTS OF REGRESSION ANALYSIS (R^2 values)
USING AIR AND SOIL TEMPERATURE VALUES
1978
LOFRECO SITE

Station Pair	Air Temperature			Soil Temperature		
	$\bar{x}$	Minimum	Maximum	$\bar{x}$	Minimum	Maximum
1-5	0.96	0.91	0.94	0.95	<u>0.74</u>	<u>0.48</u>
2-6	insufficient data			0.91	0.96	<u>0.67</u>
3-7	0.95	0.83	0.95	<u>0.75</u>	0.84	<u>0.01</u>
4-8	0.81	<u>0.96</u>	0.98	0.97	0.94	0.89
1-2	0.96	<u>0.54</u>	0.96	0.92	0.82	<u>0.49</u>

underlined values indicate no correlation

control of surface temperature and associated soil water budgets. Precipitation on the sites relates directly to interception by shrubs. Two important features of this phenomenon relate to revegetation: 1) indirect capture of rainfall and snow by shrubs, increasing the importance of these plants in all vegetation types, and 2) interception of moisture by shrubs, decreasing the effective moisture received by the herb layer.

The statistical analyses performed indicate the importance of maximum surface temperature in managing individual sites. Air temperature maximums also provide some means by which to differentiate sites. Surface temperature means and minimums do not appear to be as important with respect to individual site differences.

We conclude that the station pairs established are essentially alike, although confusion in the statistical data record will require augmentation.

In terms of the calibration of station pairs, the following will be of future importance in distinguishing station eco-climatic behavior in the area of natural versus man-induced trends:

- Stations 1 & 5
 - o significantly different air and soil maximum temperatures
 - o highest effective precipitation
- 3 & 7
 - o significantly different air temperature means, minimums and maximums
 - o lowest effective precipitation
- 4 & 8
 - o significantly different air minimum temperatures and soil maximum temperatures
 - o high effective precipitation

As a result of the priority placed on the data that it relate strongly to revegetation of disturbed sites, we feel that the woodland sites being monitored represent a duplicity. The conditions of these sites represent some important ecological differences, which when confronted with major disturbance will lose significance in terms of revegetation. Therefore, we have recommended that two of the woodland site monitoring stations be discontinued. We have selected the south-facing sites to remain because they represent the upper end of environmental stress in the woodland sites, and in this way will impart the greatest amount of information as how to handle these areas during

revegetation tasks.

We finally recommend that the six remaining stations be continued during the 1979 growing season in order to complete the continuity of the baseline data gathering period of two years. It is further considered that major changes in the ecoclimatic studies will be made during the 1980 growing season. These changes will be incumbent upon the nature of the 1979 data collection results.

POTENTIAL APPLICATION OF ECOCLIMATE DATA

The analysis and interpretation of the 1978 growing season ecoclimate data suggest a number of direct applications to 1) the understanding of herbaceous production in different vegetation types, and 2) the augmentation of revegetation of disturbed areas.

Herbaceous productivity is ostensibly controlled by temperature patterns as well as by soil chemical characteristics. The effectively longer growing season that occurs in the sagebrush-grass uplands, is product of the canopy characteristics discussed above. Canopy effects, together with more productive sorts, result in the greatest herbaceous productivity among the vegetation types on the site. Dense, over-topping characteristics of the sagebrush bottomlands retard development and productivity of the herbaceous layer in these sites. Soil surface temperatures and textural characteristics are responsible for low herbaceous production in woodland sites.

Indications for improved revegetation and persistence of established stands are as follows:

- o the use of techniques to reduce surface temperatures, such as light-colored surface materials on highly roughened surface;
- o establishment of mixed stands including shrub and grass species that will 1) establish roughness that favors strong vertical and lateral mixing of air 2) favor maximum interception of rainfall and retention of snow and 3) favor early attainment of growing temperatures;
- o roughing of rocky surfaces with addition of fine materials, where practicable in order to increase germination and decrease invasion by annual species.

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