Soil climate and plant community relationships on some rangelands of northeastern Nevada

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Abstract

Soil temperature and moisture data were collected between 1983 and 1986 on 1 forest and 11 sagebrush-dominated rangeland plant community types of the Humboldt National Forest in northeastern Nevada. Six soil parameters were used to contrast differences between the community types studied: mean annual soil temperature, mean summer soil temperature, starting date (i.e., when soil temperature at 0.5 m exceeded 5° C), growing period (i.e., number of days when soil temperature and moisture were not limiting to growth), soil degree days (i.e., number of days that soil temperature at 0.5 m exceeded 5° C), and growing period percentage (i.e., growing period/soil degree days). These soil parameters were effective in discriminating between most plant community types, yet their effectiveness varied considerably among types. Certain community types (e.g., mountain sagebrush [*Artemisia tridentata* Nutt. subspecies *vaseyana*]-bluebunch wheatgrass [*Agropyron spicatum* Pursh.]) occupy a wide range in soil temperature and moisture, which limits their indicator significance for predicting soil climate. Short growing periods of 25 to 150 days, characterize the rangeland plant community types studied. The onset of the growing period (starting date) occurs between 6 March and 1 July. Such information facilitates the determination of range readiness by plant community type in the study area.

Key Words: range readiness, soil moisture regimes, habitat types

Limited quantitative data are available concerning soil temperature and moisture (i.e., soil climate) conditions of mountainous rangelands of the Great Basin Region. Most research concerning rangeland-soil climate relationships address the autecological response of select species (Moore et al. 1972, McDonough and Harniss 1974, Campbell and Harris 1977, Sturges 1977, Platous et al. 1986). Plant community response to soil climate on western rangelands has received less attention (Branson et al. 1976, Barnes and Harrison 1982), and is seldom contrasted with criteria used in Soil Taxonomy for defining soil temperature and moisture regimes (Soil Survey Staff 1975).

This study was initiated to assess the relationship between rangeland plant community types (C.T.) and the soil temperature and moisture criteria used in Soil Taxonomy. The primary objectives of this study were (1) to assess differences in soil climate between selected Great Basin rangeland plant communities, (2) to determine how well soil climate parameters discriminate between rangeland community types, and (3) to examine how observed soil climate relationships might be used to determine range readiness.

Methods

Soil temperature and moisture data were collected from 1983 through 1986 on the Ruby, Independence, and Jarbidge Mountain Ranges of the Humboldt National Forest, northeastern Nevada. Sampling was conducted on 35 relatively undisturbed sites representative of 1 forest community type, and 11 rangeland plant community types (Table 1). A classification key was used to assign community type status to the sites (Jensen et al. 1988a).

To determine the soil moisture regime at a site, fiberglass soil moisture-temperature blocks were placed at the upper and lower boundaries of the moisture control section as defined in Soil Taxonomy (Soil Survey Staff 1975). Soil temperature was read directly with an ohmmeter, and resistance readings were taken for soil moisture (Colman and Hendrix 1949). Resistance readings were related to percent moisture by weight for each site, and soil water suction was determined with a pressure membrane apparatus (Richards 1947).

The upper boundary of the soil moisture control section was determined by computing the 0.025 m available water holding capacity depth, and the lower boundary was computed as the 0.075 m available water holding capacity depth. Water-holding capacities were calculated by use of a nomograph which addressed soil depth, texture, and rock fragment content (USDA 1980). The upper boundary of the soil moisture control section varied between 0.15 and 0.20 m depth on the sites. The depth of 0.50 m was used to index the lower boundary of the soil moisture control section on all sites since it approximated the average 0.075 m available water holding capacity depth. It is also the depth used to index soil temperature regimes in Soil Taxonomy.

Sites were sampled monthly when accessible, within 5 days of mid-month. Sampling was increased from once to twice a month when the soil temperature appeared to be reaching 5° C at a depth of .5 m, and when soil moisture was approaching 1.5 MPa suction throughout the control section. Extrapolation of data from sampling intervals immediately before and after these criteria were met on a site permitted estimation of dates associated with these two events.

Six soil climate parameters were used to characterize the sample sites (Table 2). The criteria used to define these parameters follow those used in Soil Taxonomy to characterize soil temperature and moisture regimes (Soil Survey Staff 1975). The starting date, defined by soil temperature, coincided with initiation of rapid vegetative growth of most plant species. Day of year was used to represent this parameter in this analysis. Growing period is an index of the amount of time when both soil temperature and moisture are not limiting to above ground plant growth. The suction value used in defining the growing period, less than 1.5 MPa throughout the moisture control section, probably is not limiting to most rangeland species (Branson et al. 1976, Campbell and Harris 1977). However, its use in this study is reasonable because most sites were found to dry to much greater soil suctions within a few days after this condition was met.

Mean annual soil temperature (MAST) determinations were estimated due to limited winter access, which prohibited sampling between December and April on most sites. Data for 2 months, spaced 6 months apart, were used to estimate MAST for the sites utilizing predictive soil temperature equations developed for Nevada (Schmidlin et al. 1983).

Determinations of multivariate soil parameter differences between the community types and effectiveness of soil parameters for predicting community type membership over the sites were derived

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Table 1. General site characteristics for the plant community types studied.

Community Type symbol	No. of study sites	Community type common name	Community type scientific name	Principle soil subgroup(s)	Average annual production (kg/ha-dry wt)	Averag elevatio (m)
Fir	1	Subalpine Fir	*Abies lasiocarpa* (Hook.) Nutt.	Typic Cryorthents	——	2713
ASPEN	3	Quaking Aspen	*Populus tremuloides* Michx.	Argic Pachic Cryoborolls	480	2469
CELE	1	Currleaf Mountain Mahogany	*Cercocarpus ledifolius* Nutt.	Typic Cryoborolls	410	2407
MB/BRCA	3	Snowberry/	*Symphoricarpos oreophilus* (L.) Blake	Argic Pachic Cryoborolls	1012	2042
		Mountain Big sagebrush/	*Artemisia tridenta* spp. *vaseyana* Nutt.	Pachic Cryoborolls		
		Mountain Brome	*Bromus carinatus* Hook.			
MB/AGSP	3	Snowberry/ Mountain Big Sagebrush/ Bluebunch Wheatgrass	*S. oreophilus* *A. tridentata* spp. *vaseyana* *Agropyron spicatum* Pursh.	Pachic Cryoborolls Argic Cryoborolls Typic Argixerolls	662	2090
CAREX	1	Carex Meadow Complex	*Carex* sp.	Pachic Cryoborolls	1175	2743
VA/FEID	10	Mountain Big Sagebrush/ Idaho Fescue	*A. tridentata* spp. *vaseyana* *Festuca idahoensis* Elmer	Pachic Cryoborolls Typic Cryoborolls	722	2247
VA/ELCI	2	Mountain Big Sagebrush/ Basin Wild Ryegrass	*A. tridentata* spp. *vaseyana* *Elymus cinereus* Scribn.	Argic Cryoborolls	942	2207
VA/AGSP	6	Mountain Big Sagebrush/ Bluebunch Wheatgrass	*A. tridentata* spp. *vaseyana* *A. spicatum*	Typic Argixerolls Argic Cryoborolls Typic Cryoborolls	844	2068
TR/AGSP	3	Basin Big Sagebrush/	*A. tridentata* spp. *tridentata* *Nutt.*	Typic Haploxerolls	665	1790
		Bluebunch Wheatgrass	*A. spicatum*			
AR/FEID	1	Low Sagebrush/ Idaho Fescue	*Artemisia arbuscula* Nutt. *F. idahoensis*	Typic Argixerolls	538	1786
AR/AGSP	1	Low Sagebrush/ Bluebunch Wheatgrass	*A. arbuscula* *A. spicatum*	Aridic Argixerolls	393	1871

Table 2. Definition of soil climate parameters studied.

Parameter	Definition
Soil Degree Days	No. of days when the soil temperature at a depth of 0.5 m is >5° C.
Growing Period	No. of days when the soil is moist in some part of the moisture control section when the soil temperature, at a depth of 0.5 m, is >5° C.
Growing Period Percentage	Percent of time the soil is moist in some part of the moisture control section when the soil temperature, at a depth of 0.5 m, is >5° C.
Starting Date	Date when soil temperature, at a depth of 0.5 m, exceeds 5° C.
Mean Summer Soil Temperature	Average soil temperature, at a depth of 0.5 m, for the months of June, July and August.
Mean Annual Soil Temperature	Average annual soil temperature at a depth of 0.5 m.

Note: Moist refers to soil water held at <1.5 MPa suction.

through a multiple discriminant analysis program in SAS (Helwig and Council 1979). Similar analyses have been used successfully to correlate soil properties with forest types (Gerdol et al. 1985) and to determine range condition groupings from frequency data (Mosely et al. 1986). The principal aim in discriminant analysis is to predict group membership based upon predictor variables not included in the classification process (Dillon and Goldstein 1984). The classification groups used in this study were plant community types, and the predictor variables were soil climate parameters.

Results and Discussion

Soil Climate-Plant Community Relationships

Records from 3 weather stations in the study area (i.e., Mountain City, Independence Mountains, elevation 1,796 m; North Fork, Independence Mountains, elevation 2,100 m; and Lamoille, Ruby Mountains, elevation 1,847 m) indicated that average annual precipitation ranged from 12% below to 48% above the 20-yr long-term average of 350 mm during the study period (NOAA 1986). Average precipitation for the months of April, May, and June considered collectively ranged from 54% below to 64% above the 20-yr long-term average of 110 mm.

Soil temperature and moisture regimes in the study area have been previously described by Jensen et al. (1988b). Cryic soil temperatures are found at 68% of the study sites, while 9% have frigid, and 23% have mesic soil temperatures. Most of the plant community types (Table 1) with basin big sagebrush, mountain big sagebrush or low sagebrush as dominant shrub species have aridic soil moisture regimes. The snowberry and quaking aspen C.T. occur on aridic, xeric, and ustic soils. The subalpine fir and carex meadow C.T.'s have ustic and udic soil moisture regimes, respectively.

The plant communities studied display both wide ranges and significant differences in soil climate parameters (Tables 3 and 4). Low sagebrush dominated communities possess much shorter growing periods and warmer soil temperatures than other community types. The subalpine fir, carex, and quaking aspen C.T. tend to have the coolest soil temperatures despite having some of the longest growing periods. Sites with mountain big sagebrush as the dominant shrub species generally do not differ significantly from each other in average soil parameter values.

Relatively short growing periods for above ground plant growth exist on most sites (Table 3). The short growing period present is a result of soil temperature initially limiting plant growth, followed by rapid depletion of available soil moisture after the snowpack melts in the spring. Convective rainstorms in the summer and fall are not effective in recharging soil moisture in the control section on most of these northern Nevada range sites. A limited time period exists for most plants to grow under these conditions. The same situation has been documented for southern Idaho range

Table 3. Soil climate parameter values by plant community type.

Plant community type		Soil degree days	Growing period (days)	Growing period percentage	Starting date	Mean summer soil temperature (°C)	Mean annual soil temperature (°C)
FIR	X*	93	70	75	6/22	8	4
	S	18	14	1	11 days	1	0
	R	80 to 105	60 to 80	75 to 76	6/15 to 7/1	7 to 8	4
	N	2	2	2	2	2	2
ASPEN	X	132	54	40	5/26	10	5
	S	29	11	10	17 days	2	1
	R	100 to 185	30 to 70	28 to 64	4/25 to 6/20	7 to 14	4 to 7
	N	10	10	10	10	9	8
CELE	X	167	49	28	5/18	11	6
	S	29	10	3	14 days	1	2
	R	150 to 200	40 to 63	26 to 32	5/1 to 6/3	10 to 12	5 to 8
	N	4	4	4	4	4	3
MB/BRCA	X	160	70	43	5/8	13	7
	S	22	25	13	19 days	2	1
	R	125 to 195	40 to 120	28 to 70	4/1 to 6/10	9 to 16	5 to 8
	N	14	14	14	14	12	10
MB/AGSP	X	173	45	27	5/5	15	8
	S	27	11	8	14 days	3	1
	R	136 to 230	30 to 60	16 to 39	4/1 to 5/20	10 to 20	6 to 10
	N	15	15	15	15	11	8
CAREX	X	137	130	95	6/6	9	4
	S	16	16	6	11 days	2	2
	R	122 to 154	120 to 150	89 to 100	6/1 to 6/20	8 to 11	2 to 6
	N	3	3	3	3	3	3
VA/FEID	X	157	50	32	5/9	12	6
	S	28	11	11	24 days	2	2
	R	110 to 230	32 to 70	23 to 64	3/15 to 6/20	8 to 16	4 to 9
	N	21	21	21	21	18	13
VA/ELCI	X	152	53	35	5/13	14	7
	S	12	14	10	15 days	3	1
	R	135 to 165	40 to 75	25 to 50	4/20 to 6/1	11 to 17	5 to 8
	N	7	7	7	7	6	5
VA/AGSP	X	177	56	31	5/2	14	7
	S	21	16	10	15 days	3	1
	R	140 to 215	34 to 90	18 to 50	4/1 to 6/1	10 to 17	5 to 9
	N	18	18	18	18	14	12
TR/AGSP	X	191	62	32	4/16	15	8
	S	29	16	6	20 days	2	2
	R	150 to 225	40 to 90	23 to 40	3/18 to 5/15	13 to 17	5 to 11
	N	10	10	10	10	7	7
AR/FEID	X	190	27	14	4/9	17	9
	S	31	3	4	34 days	1	2
	R	165 to 225	25 to 30	11 to 18	3/6 to 5/15	16 to 17	7 to 11
	N	4	4	4	4	3	3
AR/AGSP	X	228	32	14	4/1	21	11
	S	4	3	1	0 days	1	4
	R	225 to 230	30 to 34	13 to 15	——	21 to 22	10 to 12
	N	3	3	3	3	3	2

*X = means; S = standard deviation; R = range; N = number of site years.

lands (Jensen 1984), suggesting that short growing periods may limit production on many rangeland sites of the Great Basin Region.

Initiation of the growing period and its duration display differences between the rangeland community types studied (Table 3). Average starting dates for vegetation growth on the study sites ranged from 1 April on the low sagebrush-bluebunch wheatgrass C.T. to 22 June on the subalpine fir C.T. The average number of days when soils have available moisture in the control section following onset of the starting date (i.e., growing period) ranged from 27 days on the low sagebrush-Idaho fescue C.T. to 130 days on the carex meadow C.T.

Phenological stages of grass, forb, and shrub species are correlated with advance of growing period in this study. Most plant species initiate rapid vegetative growth when the soil temperature at 0.5 m exceeds 5° C. By the end of the growing period most grasses have set seed, forbs have desiccated, and shrubs have initiated seed set. A significant linear correlation ($P<.05$) exists between starting date and elevation over the study sites (Fig. 1). The slope of this regression suggests that the onset of the growing season is delayed approximately 6 days as elevation increases by 100 m.

Discrimination of Plant Community Type by Soil Climate Parameters

Multivariate analysis of soil climate parameters demonstrated varying degrees of dissimilarity between community types (Table 5). Subalpine fir, carex and low sagebrush C.T.'s display the largest Mahalanobis' distances between groups, which indicates that they occupy unique settings with respect to the soil parameters. Quaking aspen and curlleaf mountain mahogany C.T.'s show interme-

Table 4. Comparison of mean soil climate parameter values by plant community type.

Growing Period Percentage

CAREX	FIR	MB/BRCA	ASPEN	VA/ELCI	VA/FEID	TR/AGSP	VA/AGSP	CELE	MB/AGSP	AR/FEID	AR/AGSP
95	75	43	40	35	32	32	31	28	27	14	14

Growing Period (days)

CAREX	FIR	MB/BRCA	TR/AGSP	VA/AGSP	ASPEN	VA/ELCI	VA/FEID	CELE	MB/AGSP	AR/AGSP	AR/FEID
130	70	70	62	56	54	53	50	49	45	32	27

Starting Date

FIR	CAREX	ASPEN	CELE	VA/ELCI	VA/FEID	MB/BRCA	MB/AGSP	VA/AGSP	TR/AGSP	AR/FEID	AR/AGSP
June 22	June 6	May 26	May 18	May 13	May 9	May 8	May 5	May 2	April 16	April 9	April 1

Mean Summer Soil Temperature (°C)

FIR	CAREX	ASPEN	CELE	VA/FELD	MB/BRCA	VA/ELCI	VA/AGSP	MB/AGSP	TR/AGSP	AR/FEID	AR/AGSP
8	9	10	11	12	13	14	14	15	15	17	21

Mean Annual Soil Temperature (0° C)

FIR	CAREX	ASPEN	CELE	VA/FEID	MB/BRCA	VA/ELCI	VA/AGSP	MB/AGSP	TR/AGSP	AR/FEID	AR/AGSP
4	4	5	6	6	7	7	7	8	8	9	11

Soil Degree Days

FIR	ASPEN	CAREX	VA/ELCI	VA/FEID	MB/BRCA	CELE	MB/AGSP	VA/AGSP	AR/FEID	TR/AGSP	AR/AGSP
93	132	137	152	157	160	167	173	177	190	191	228*

*Means underlined by same line are not significantly different ($P<.05$) as determined by Waller-Duncan Bayes LSD.

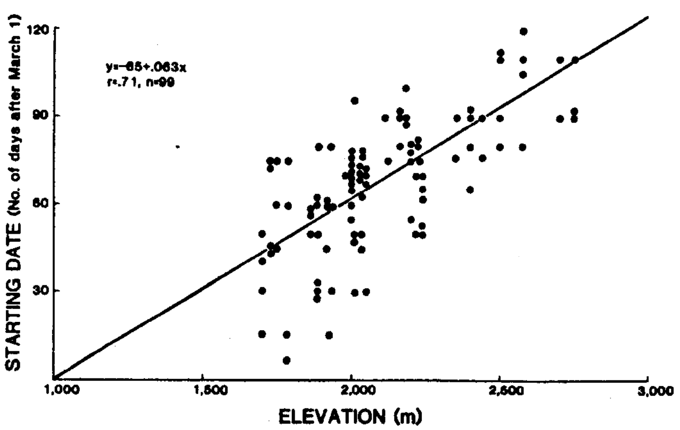

Fig. 1. *Relationship between starting date and elevation for the study area.*

diate distance values from the snowberry, basin big sagebrush and mountain big sagebrush C.T.'s. The distances observed between the snowberry, basin big sagebrush, and mountain big sagebrush C.T.'s are generally small, which indicates that they occupy sites with similar soil temperature and moisture conditions.

The soil climate parameters studied display considerable variability in their effectiveness to discriminate between plant community types (Table 6). Overall, 54% of the sites are correctly assigned to their community type based upon the soil criteria. Soil parameters are very effective in predicting site membership within the subalpine fir, carex, quaking aspen, curlleaf mountain mahogany, and low sagebrush-bluebunch wheatgrass C.T.'s. This is presumably due to the fact that these community types are characterized by extreme values for the soil parameters studied (Table 3). Moderate correspondence between soil parameters and community type is achieved in the basin big sagebrush-bluebunch wheatgrass, and snowberry C.T.'s. Soil parameters are not good predic-

Table 5. Mahalanobis generalized distance between plant community types based upon soil climate parameters.

	FIR	CAREX	ASPEN	CELE	MB/BRCA	MB/AGSP	VA/FEID	VA/ELCI	VA/AGSP	TR/AGSP	AR/FEID	AR/AGSP
FIR												
CAREX	6.9											
ASPEN	5.8	6.1										
CELE	7.7	6.6	2.8									
MB/BRCA	6.8	5.6	2.2	2.6								
MB/AGSP	7.4	7.5	3.2	2.6	2.5							
VA/FEID	6.6	6.6	1.8	1.9	1.5	1.7						
VA/ELCI	6.8	7.0	2.4	2.9	1.9	1.4	1.4					
VA/AGSP	7.1	6.7	2.5	2.3	1.4	1.2	0.9	1.1				
TR/AGSP	7.4	7.0	3.0	2.6	1.8	1.3	1.5	1.6	0.8			
AR/FEID	7.6	9.4	4.6	4.6	4.5	2.3	3.3	3.0	3.1	5.2		
AR/AGSP	8.6	10.8	7.1	6.6	6.7	4.6	5.8	5.4	5.4	2.9	2.9	

Table 6. Confusion matrix of predicted community type membership of the samples based upon soil climate criteria. The underlined values represent the relative percentage of samples correctly assigned to their appropriate community type.

Predicted community type membership	Actual Community Type											
	FIR	CAREX	ASPEN	CELE	MB/BRCA	MB/AGSP	VA/FEID	VA/ELCI	VA/AGSP	TR/AGSP	AR/FEID	AR/AGSP
	n=2	n=3	n=8	n=3	n=10	n=8	n=13	n=5	n=12	n=7	n=3	n=2
FOR	100											
CAREX		100										
ASPEN			88		10	12	15					
CELE				100				20	8			
MB/BRCA					50		8		17			
MB/AGSP						63	15	20	17		33	
VA/FEID					10		39	20				
VA/ELCI					20	12	8	40	8	29		
VA/AGSP					10	13			8			
TR/AGSP			12				15		17	71		
AR/FEID									25		34	
AR/AGSP											33	100

n = number of site years
Overall percent of community types classified correctly = 54%.

tors of community type within the mountain big sagebrush types and the low sagebrush-Idaho fescue type. This is partially due to the fact that these community types occupy a wide range of soil temperature and moisture conditions, which often overlap. Additionally, these community types probably respond to other environmental parameters not measured (e.g., snow depth). These factors contribute to the poor correspondence observed.

Generalized relationships between soil climate and community indicator plant species have been developed for a variety of western rangelands (West et al. 1978, Mueggler and Stewart 1980, Hironaka et al. 1983, Platous et al. 1986). These studies provide useful modal concepts of how rangeland plant communities respond to climate, yet they do not quantitatively address the inherent variability of such responses. The discriminant analysis of soil climate parameters and plant community types (Table 6) suggests that the indicator significance of community types for predicting soil climate is highly variable. Community types which occupy a wide range of soil climate (e.g., VA/AGSP) provide a poor indication of soil climate conditions present at a site. Land managers must consider such variability before assessing site potentials for an area based upon presence of a given plant community type.

Determination of Range Readiness

Most land management agencies utilize visual assessments of plant species phenological stage when determining the appropriate time to initate grazing pressures within a given area (i.e., its range readiness). This method has a disadvantage in that it is not possible to cover all range allotments in a given year due to financial constraints. An understanding of the start and duration of a particular plant community's growing period provides managers with an alternative tool for assessing range readiness.

In this study, onset of the growing season at a site is delayed by approximately 6 days for each 100 m rise in elevation (Fig. 1). The average termination of the growing period is reached, depending on community type, between 27 and 130 days after onset (Table 3). Documentation of a starting date at the lower elevation of an allotment can be used to approximate advance of the growing period by plant community type throughout the allotment based upon information provided in Table 3 and Figure 1.

When growing period stages are correlated with plant phenological development, range readiness may be estimated for high elevation sites based upon sampling of low elevation soil temperatures in the early spring. The following is an example of how this approach might be implemented in range management planning.

Range readiness is to be predicted, in the spring, for a 1 pasture, continuous use, grazing system. The phenological stage used to indicate range readiness is seed set of grass species, which is reached by the end of the growing period. The pasture is comprised of three different community types (i.e. AR/AGSP, VA/FEID, and MB/BRCA) whose midpoint elevations are 1,500 m and 2,000 m and 2,500 m respectively.

Temperature sampling conducted on the AR/AGSP C.T. indicates that its starting date is April 1. The average growing period for this type is 32 days (Table 3). Based upon the plant phenology criterion used, this community is predicted to reach range readiness by 3 May (i.e., 32 days after 1 April).

Since the onset of the growing season is delayed approximately 6 days for each 100 m rise in elevation (Fig. 1), the starting date recorded at the AR/AGSP C.T. may be used to approximate starting dates for the other community types in the pasture. Starting dates for the VA/FEID and MB/BRCA C.T.'s are predicted to begin on 1 May and 31 May, by this approach. Range readiness is reached approximately 50 and 70 days after those dates, respectively. The method outlined above has proven useful in the prediction of range readiness on the Humboldt National Forest, and should be considered by other managers in the Great Basin.

Conclusions

Soil temperature and moisture data are important to soil classification and management of rangelands in the Great Basin Region. Such information is limited, which frustrates attempts to quantify land potentials. Data from this study indicate that a short period of time exists when either soil temperature or soil moisture are not limiting to plant growth on these rangelands. Due to the short growing period present, managers need to utilize soil climate data in rangeland planning. Calculation of the onset and duration of the growing period operable within a community type facilitates the prediction of range readiness. Such data, however, are not available for other plant community types of the Great Basin. Additional soil temperature and moisture research is required if resources are to be optimally managed.

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