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SOIL MOISTURE AND TEMPERATURE REGIMES IN BEAVERHEAD COUNTY, MONTANA

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ABSTRACT

In the summer of 1977 and 1978 soil moisture and temperature were measured at sites in Beaverhead County, Montana, a cold and dry region where aridic moisture regimes may occur in combination with cryic temperature regimes. The combination was not found in the areas tested but probably occurs elsewhere in the county. About 2000m separated cryic and frigid summer soil temperature regimes.

INTRODUCTION

Soil Taxonomy (Soil Survey Staff 1975) emphasizes soil moisture and temperature as differentiating criteria. Twenty of the 30 sub-orders of soil found in the United States are defined in terms of moisture and temperature, constituting over three-fourths of U.S. land surface. Few data, however, are available to support these criteria. Smith (1973) noted that "few observations have been made on duration of dryness . . .", though considerable "common knowledge" is available. This deficiency in supporting data has frustrated soil classification attempts.

The shortage of soil moisture and temperature data became apparent during a soil survey of lands administered by the Bureau of Land Management (BLM) in Beaverhead County, in southwestern Montana. This part of Montana, generally above 1800m, has cold soils. Located in the rain shadow of the Bitterroot Range to the west, the county is dry. Soil taxonomy does not adequately cover this combination of cold, dry soils.

The study was designed to collect preliminary data on soil moisture and summer soil temperature regimes of a number of soils in Beaverhead County, to determine if the moisture regimes were aridic and if temperature regimes were frigid or cryic. Where boundaries fall between cryic and frigid regimes is an important question in the state. Whether aridic moisture and cryic temperature regimes occur together was specifically tested.

LITERATURE REVIEW

Soil Moisture

Soil Taxonomy recognizes five moisture regimes. Aquic is saturated and not part of this study. Xeric is characteristic of Mediterranean climates where winter leaching occurs; Beaverhead County is too cold for this regime. Abbreviated criteria for the remaining three moisture regimes are given in Table 1.

Few studies have been made of moisture regimes in the northern Rockies. Rawls et al. (1973) measured moisture regimes of three soils (Xeric Torriorthent, Calcic Argixeroll, Pachic Cryoboroll) near Boise, Idaho, about 400km southwest of the Beaverhead area. Annual precipitation in the area of the Xeric Torriorthent averages 23cm and 27cm for the Calcic Argixeroll, a situation similar to that of Dillon, Montana (24cm), Beaverhead's county seat and the community nearest the study area.

Soil Temperature

Six temperature regimes are recognized in *Soil Taxonomy* for soils whose temperatures in the summer and winter vary by more than 5°C. Three of the six may occur in Montana; these three are shown in Table 2.

The soil-temperature regimes in Montana are usually either cryic or frigid; pergelic occurs only at high elevations (Munn and Nielsen 1979). Relief in western Montana varies widely; an elevation representing the 15°C mean summer soil temperature is an important criterion separating the two regimes.

Nimlos' (1971) study of soil temperature regimes of seven sites in the Lubrecht Experimental Forest (elevation 1216 to 1794m), located about 160km north of Dillon, showed that all sites except one met the requirements of the cryic temperature regime. The exception was at the lowest elevation and on a steep, south-facing slope with an open canopy of *Pinus ponderosa*. The site had a mean annual soil temperature of 8°C and a mean summer soil temperature of 16°C.

Jensen (1980) has characterized soil temperature regimes on the Caribou National Forest in southern Idaho. He recognized two categories of slopes based on the amount of solar radiation received: high intensity aspects are south to southwest exposures supporting sagebrush/grass vegetation communities; low intensity aspects are north to northeast exposures supporting lodgepole pine/mountain brush/pinegrass types. He found that cryic and mesic regimes dominated the Caribou; and that the 15°C isotherm, the elevational break between cryic and frigid temperature regimes, was about 1900m on south aspects and 1600m on north aspects.

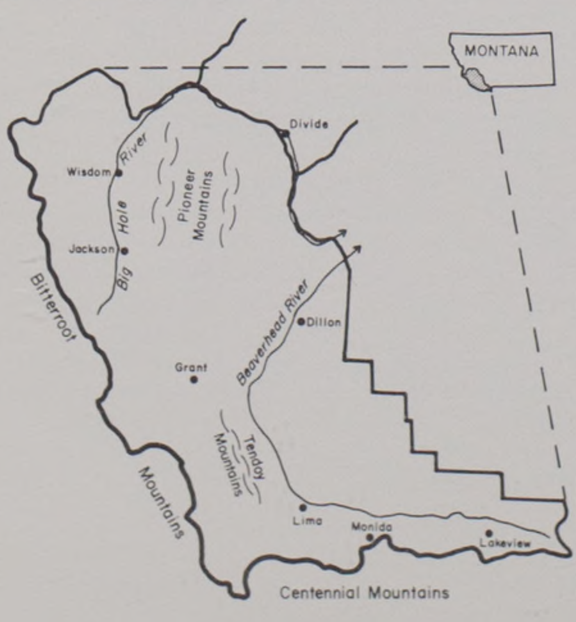
Munn and Nielsen (1979) developed equations for predicting mean annual and summer soil temperatures from site characteristics (latitude, slope gradient, aspect and elevation). Their data show the 15°C elevational break for sites in the latitude of Dillon and on flat slopes to be about 1800m.

DESCRIPTION OF STUDY AREA

Beaverhead County is a series of high and dry mountain valleys in southwestern Montana. Its boundary with Idaho is the Bitterroot Range in the west and southwest; the southern boundary, the Centennial Mountains, is part of the continental divide (Figure 1). The lowest elevation in the county is about 1440m, where the Big Hole River exits; mountain peaks over 3000m are scattered throughout the county.

Vegetation includes mountain bunchgrass and sagebrush at lower elevations and forest at higher elevations. The forests are managed by the Forest Service; lower-elevation, irrigable soils are privately owned. The foothills between are public lands managed by the BLM.

Figure 1 Beaverhead County, Montana



Mean monthly and annual precipitation at four stations in or near Beaverhead County is presented in Table 3. Similar data for air temperature appear in Table 4. These stations, situated at low elevations, are representative of lands administered by the BLM. Locations are shown in Figure 1.

Table 1 Abbreviated Criteria for Some Common Moisture Regimes and their Associated Climates in Montana

MOISTURE REGIME	ABBREVIATED CRITERIA	CLIMATE
Udic	Not dry for 90 days cumulative	Humid
Ustic	Dry 90 or more cumulative days but not more than one-half the time temperature is > 5°C	Sub-humid or semi-arid
Aridic or Torric	Dry more than one-half the time temperature is > 5°C. Never moist more than 90 consecutive days when temperature is > 8°C.	Desert

Source: Soil Survey Staff 1975.

Table 2 Abbreviated Criteria for Some Common Soil Temperature Regimes in Montana

TEMPERATURE REGIME	ABBREVIATED CRITERIA (well-drained mineral soils without 0 horizons)	
	Mean Annual (°C)	Mean Summer (°C)
Pergelic	< 0	—
Cryic	0-8	< 15
Frigid	0-8	> 15

Source: Soil Survey Staff 1975.

Table 3 Mean Monthly and Annual Precipitation at Four Stations in or near Beaverhead County, Montana

MONTH	STATION			
	Dillon‡	Divide†	Lima‡	Lakeview‡
	elevation (m)			
	1583	1641	1902	2030
	— centimeters —			
January	0.7	1.5	0.7	4.3
February	0.6	1.0	0.7	3.0
March	1.3	1.7	1.3	4.1
April	2.1	2.8	3.8	2.3
May	4.2	3.7	4.8	6.6
June	5.7	6.4	6.0	8.3
July	2.2	2.9	2.8	3.1
August	2.1	3.1	3.0	3.4
September	2.4	2.9	2.7	3.8
October	1.2	2.1	1.7	3.7
November	1.1	1.5	0.9	4.0
December	0.7	1.7	0.8	4.0
Annual	24.2	31.2	27.6	51.9

†1955-1957
‡all years of record

Source: National Oceanic and Atmospheric Administration 1978.

About one-half the annual precipitation falls during May, June and July at Dillon, Divide and Lima; a slightly lower percentage falls at Lakeview. As in most mountainous terrain, a strong correlation exists between elevation and precipitation; the precipitation at Lakeview, the highest station, is more than double (52cm) that at Dillon, the lowest station (24cm). The effect of elevation on precipitation is even more evident when comparing valley bottoms with mountain peaks. For instance, Garfield Mountain (3324m), 13km south of Lima (1902m), receives almost three times more precipitation than Lima (Ross and Hunter 1976).

The Dillon airport is the closest weather station to Badger Pass, where the moisture study was undertaken. Dillon's seasonal precipitation (April to September) for 1977 and 1978 was 23.2 and 18.9cm, 124 and 101 percent of the long-range means. Annual precipitation for the same years was 29.6 and 21.1cm, 122 and 87 percent of the long-range means.

Figure 2 represents a water balance for the Dillon station. Curves for the other stations differ as to the termination date of water availability: May 20 for Dillon; June 10, June 20, and September 20 for Lima, Divide, and Lakeview, respectively. Comparing these graphs to those on pages 55 and 56 of *Soil Taxonomy* indicates the moisture regime at Dillon is probably aridic, the others ustic.

July is the warmest month, January the coldest. Mean annual air temperatures at the stations, strongly correlated with elevation, vary from 1.6 to 5.9°C. Mean annual soil temperature can be estimated by adding 1°C to the mean annual air temperature (Soil Survey Staff 1975). These calculations suggest that mean annual soil temperatures in Beaverhead County should be between 3°C and 7°C, depending upon elevation. The soil temperature regime should be cryic or frigid.

As indicated in Table 5, air temperature during 1977 and 1978 was nearly normal, with 1978 cooler than 1977.

Soils

Due to varying geologic and geomorphic features, a variety of soils exists in Beaverhead County. Soil maps are available for 280,000 of the county's 1.2 million hectare. The mapping legend contains 61 taxonomic units and 258 mapping units.

Typic Cryoborolls, the most common taxonomic unit within the survey area, occurs from grass-covered foothills (above 2000m) to high mountain peaks. Other common soils are Argic Cryoborolls and Calcic Cryoborolls. Aridic Haploborolls, Borollic Haplargids and Borollic Calciorthids are common among lower foothills (below 2000m), basins and valley bottoms.

METHODS

Soil moisture was measured at ten sites on a 20km, east-west transect over a north-south ridge at Badger Pass. Site elevations ranged from 1763 to 2052m. Each site was sampled 12 times during 1977, usually every two weeks from May 20 through October 30. In 1978 samples were taken from mid-April to early October; soil temperature was >5°C.

The soil moisture control section was determined gravimetrically for each profile, using guidelines given in *Soil Taxonomy*. Samples were obtained from the upper and lower limits of the control section. Coarse fragments were not sieved off, a possible source of error in testing loamy skeletal soils, though most fragments were picked out by hand at the time of sampling. The moisture curves were generally stable, indicating little or no error.

Fifteen-bar water retention data, determined with a ceramic pressure plate, proved unreliable. Low plateaus in the moisture curves indicated when the soil was dry.

Using a metal dial thermometer together with a glass mercury thermometer for calibration, soil temperature was measured at a depth of 50cm on 34 sites in the survey area during 1977 and on 59 sites during 1978.

Table 4 Mean Monthly and Annual Air Temperature at Four Stations in or near Beaverhead County, Montana

MONTH	STATION			
	Dillon‡	Divide†	Lima‡	Lakeview‡
	— degrees centigrade —			
January	-6	-7	-8	-11
February	-4	-4	-6	-9
March	-1	-2	-3	-6
April	5	3	3	0
May	10	8	8	7
June	14	13	11	11
July	19	17	16	14
August	18	16	15	14
September	12	11	11	9
October	7	6	6	3
November	0	-1	-2	-4
December	-5	-5	-7	-10
Annual	5.9	4.8	3.8	1.6

†1955-1976
‡all years of record

Source: National Oceanic and Atmospheric Administration 1978.

Table 5 Average Summer Air Temperatures at Dillon, Montana in 1977 and 1978

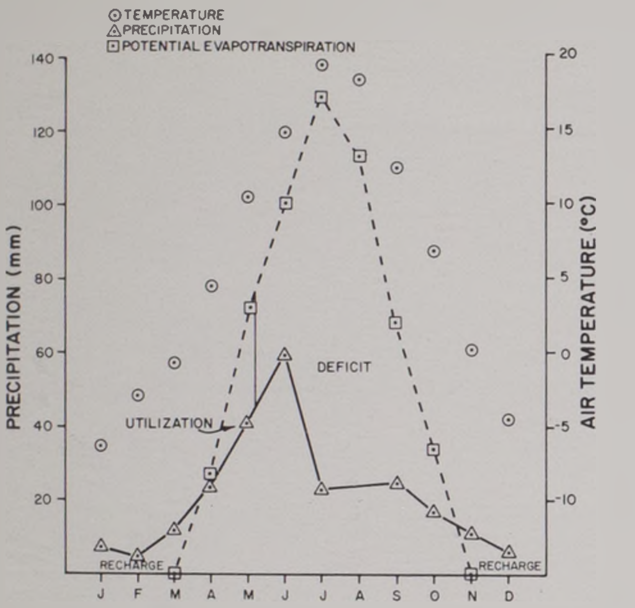
MONTH	1977	1978	LONG-RANGE AVERAGE
	— degrees centigrade —		
June	16.3	14.3	14
July	17.4	18.1	19
August	17.7	17.7	18
3-Month Mean	16.9	16.4	17

Source: National Oceanic and Atmospheric Administration 1978

Table 6 Number of Days Soil Temperatures of Beaverhead County Stations with Cryic Temperature Regimes Are >5°C and >8°C

STATION	LOCATION	ELEVATION	DAYS >5°C	DAYS >8°C
		—meters—		
5	Badger Pass	2006	150	120
6	Badger Pass	2052	150	120
7	Badger Pass	2006	150	105

Figure 2 **Climatic Data and Soil Water Balance for Dillon, Montana**



RESULTS

Soil Moisture

Sampling during summer 1977 was incomplete because of the press of field operations. The data were thus considered preliminary to the 1978 sampling. The 1977 data showed several periods of dryness and rewetting following spring and summer rains. A heavy rain (1.5cm) on July 24 was followed by a long dry period until September 30, during which less than 2.0cm of precipitation fell. The soils were dry during much of this period.

Figure 3 shows the soil moisture pattern for station six, which has a cryic temperature regime. Moisture in the soil, recharged during the spring, is gradually used until profiles are dry; recharge occurs in early September. The period of dryness was 40 days in the upper part of the control section, 60 in the lower. The dry period in the other profiles with cryic temperature regimes was between 15 and 60 days.

Two requirements exist for aridic moisture regimes. First, the soil must be dry more than one-half the time the temperature is > 5°C. A dry soil lacks available moisture in the control section (Soil Survey Staff 1975). As indicated in Table 6, the temperature at Badger Pass (site 6) is > 5°C for 150 days. The site, however, dry 60 days during which the temperature is > 5°C, thus fails to meet this requirement, as do the other two cryic stations.

The aridic classification also requires that soils never be moist during more than 90 consecutive days when the temperature is > 8°C. The soils of Badger Pass, > 8°C between 105 and 120 days (Table 4), need be dry only between 15 and 30 days (or more) to meet this requirement. This was the case during 1977 and 1978. By this criterion the soils of Badger Pass are aridic. Given Badger Pass' moisture regime, however, soils with cryic temperature regimes are ustic, but are nearly aridic.

Soil Temperature

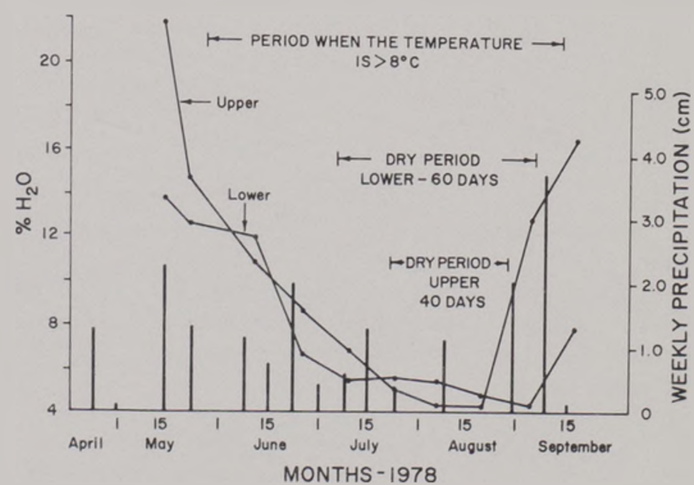
Table 7 presents soil temperature data for 28 of the 59 sites sampled. Complete data are presented for the Badger Pass transect. Data near the elevation of 15°C summer temperature for other transects are also shown. The mean is based on data from 1977 and 1978, except for two stations, where the mean is based on data from 1978 only. Most stations had cooler soil temperatures in 1978 than in 1977, reflecting cooler air temperatures.

Both cryic and frigid summer soil temperatures exist in Beaverhead County; the elevational break between the two temperature regimes varies geographically. On gentle slopes in the Badger Pass area the break between the two occurs near 2000m. The elevational line is 200m lower in the Wise River area, 60km north of Badger Pass. Other areas observed appeared similar to Badger Pass.

The Soil Conservation Service's procedure for estimating soil temperature regimes from air temperatures shows the temperature regime for the four weather stations in Beaverhead County as being frigid or cryic, without differentiations being made between the stations (Dierking 1980). This study indicates they should be classified as frigid, except the Lakeview station, which should be cryic.

The 15°C isotherm should occur at higher elevations south of Montana. Jensen (1980), however, found it existed at 1913m on south aspects and 1591 on north aspects. This suggests considerable local variation exists in the 15°C isotherm.

Figure 3 **Soil Moisture (Line Graph) and Weekly Precipitation (Bar Graph) for Station 6 on Badger Pass at Two Positions in the Control Section for Spring and Summer 1978**



DISCUSSION

The soils of Beaverhead County include cryic and frigid temperature regimes. The 15°C summer soil temperature isotherm which separates the two regimes occurs at approximately 2000m, though that elevation varies slightly with vegetative cover, aspect and location. The elevational position of the 15°C isotherm appears fairly well established. The cryic temperature regime is fairly common.

Soil moisture regimes in Beaverhead County are not as precisely defined as the elevation of the 15°C isotherm, though it appears both the aridic and the more common ustic regimes occur there.

This study's soil moisture-temperature transect was placed on Badger Pass because of accessibility and the availability of the soil maps that had resulted from this study during early summer. Other Beaverhead County areas were later discovered to have better possibilities for testing the presence of the aridic-cryic combination of moisture and temperature. For instance, Basin Creek watershed, higher and cooler, has *Stipa comata* type vegetation, whereas *Festuca idahoensis* is the dominant grass on Badger Pass. *Festuca idahoensis* normally occurs on wetter sites than *Stipa comata*. If the higher soils on Badger Pass are cryic and marginally aridic, it is possible that the aridic-cryic combination occurs in other parts of Beaverhead County and that the stands of *Stipa comata* at higher elevations need to be sampled for the presence of the aridic regime.

Definitions of soil moisture regimes are tentative; modifications may be required (Soil Survey Staff 1975). This study's data may suggest appropriate modifications.

The separation of soils supporting *Festuca idahoensis* and those supporting *Stipa comata* is important in range management in Beaverhead County. *Festuca idahoensis* sites have considerable herbage production and ground cover; soils are usually Cryoborolls. *Stipa comata* stands have less production and ground cover; soils are Aridisols or aridic subgroups of Mollisols (Munn et al. 1978). Using *Stipa comata* rather than *Festuca idahoensis* to define aridic moisture regimes might be logical for Beaverhead County. This study's preliminary data suggests a *Stipa comata* criterion might define aridic moisture regimes when soils are dry and temperatures are >5°C; the requirement could be dropped that soils go 90 consecutive days without being moist when temperatures are >8°C. This latter temperature is more relevant for agronomic species than for native grasses.

Soils on top of Badger Pass are cryic; they are also ustic, even though they meet the aridic requirement that the soil not be moist more than 90 consecutive days when temperatures are >8°C. If other soils in Beaverhead County prove to be aridic as well as cryic, a modification in this soil-classification requirement may be desirable.

CONCLUSIONS

These preliminary data from Beaverhead County suggest that:

1. Cryic and frigid soil temperature regimes occur in the county. The 15°C isotherm separating the two is at about 2000m, the exact elevation varying with aspect, cover and location.

2. Soil moisture regimes on Badger Pass are marginal between aridic and ustic. The definition of aridic moisture should perhaps be changed to eliminate the requirement concerning the period when the soil is >8°C.

3. Cryic-aridic combinations of temperature and moisture probably occur in parts of Beaverhead County when the flora indicates drier sites than those found on Badger Pass.

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Table 7 Mean Summer Soil Temperature for Badger Pass and Other Areas in Beaverhead County

STATION	ELEVATION	ASPECT	SLOPE	MEAN SUMMER TEMP 1977	1978	MEAN	REGIME
			Badger Pass				
	—meters—			—degrees cent—			
6	2052	N	6	15.0	12.2	13.6	cryic
7	2006	W	6	14.7	14.0	14.4	cryic
5	2006	SE	5	15.0	13.7	14.4	cryic
4	1946	E	2	15.5	15.2	15.4	frigid
8	1946	W	7	16.5	15.3	15.9	frigid
3	1885	E	3	16.3	15.8	16.0	frigid
9	1885	SW	5	17.3	15.7	16.5	frigid
10	1824	SW	1	16.7	14.7	15.7	frigid
2	1824	ESE	4	16.2	17.3	16.8	frigid
1	1763	E	2	16.7	17.8	17.2	frigid
			Wise River				
3	1827	NW	28	—	9.5	9.5	cryic
5	1806	SE	16	—	16.2	16.2	frigid
4	1794	SSW	25	—	14.2	14.2	cryic
9	1781	W	10	—	15.3	15.3	frigid
			Basin Creek				
3	2067	NE	2	14.8	14.5	14.6	cryic
7	2067	NW	7	14.5	14.5	14.5	cryic
2	2037	ENE	8	15.8	14.3	15.0	frigid
8	2037	W	10	16.2	15.7	16.0	frigid
9	2006	NW	2	16.5	16.2	16.4	frigid
			Basin Flats				
3	2098	S	6	15.7	13.8	14.8	cryic
4	2067	—	1	15.7	13.8	14.8	cryic
2	2067	—	1	15.7	14.7	15.2	frigid
1	2037	—	1	17.5	14.8	16.2	frigid
			Sheep Creek				
6	2006	W	9	—	14.5	14.5	cryic
7	1945	SE	5	—	15.3	15.3	frigid
			Centennial Valley				
5	2060	SW	10	16.0	15.2	15.6	frigid
7	2022	—	1	15.3	15.5	15.4	frigid
6	2006	—	1	14.2	14.2	14.2	cryic