AN ABSTRACT OF THE THESIS OF

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The effects of aspect, canopy, elevation, and season both singly and in combination on soil temperatures at 50 cm depths were evaluated.

The objectives of the study were (i) to develop a standard procedure for obtaining soil temperature data adequate to classify soils at the family and great group levels, (ii) to evaluate the effects which elevation, canopy, aspect, and season singly and in combination have on soil temperature, (iii) to evaluate the durability and consistency of selected instruments, and (iv) to test whether the months used by the Soil Survey Staff (1975) for calculating mean summer and winter temperatures are appropriate for this locality.

Monitoring sites were established at seven elevations spanning soil temperature regimes from mesic to cryic. At each elevation, sites were located on both northerly and southerly aspects, and within each aspect under full forest canopy and in an opening or clearcut. Temperatures were read monthly using four different instruments. Marys Peak, in the Oregon Coast Range, was chosen as the general location for the study.

A number of methods were used in analysis of the data. Graphs

showing various temperature interactions among the main site factors were developed. The Sips statistical package (Rowe and Brenne, 1981) was used to develop analysis of variance tables for seasons as defined by Soil Taxonomy as well as an alternative set of seasons, which were based on the observation in the data that maximum summer and minimum winter temperatures lag behind the periods as defined in Soil Taxonomy. Analysis of variance tables were constructed for these seasons both with and without data from 610 meters, to evaluate data from an unusually warm site at this level. This statistical package was also used to develop a regression model utilizing Soil Taxonomy seasons without data from 610 meters.

Using Soil Survey Staff's (1975) seasons but excluding data from 610 meters, elevation by canopy, aspect by canopy, elevation by season, canopy by season, and aspect by season were statistically significant at the .05 level. This was mostly attributed to the insulation effect provided by the closed canopy resulting in reduced direct solar radiation reaching the soil surface.

There was evidence of possible iso-temperature regimes occurring under closed canopy conditions at all elevations on both aspects if seasons were defined according to Soil Survey Staff (1975) guidelines. However, if seasons are defined to truly represent the three consecutive coldest and warmest months, then only two sites remained iso.

A regression model with an R^2 value of .98 was developed for the Marys Peak area. Variables included aspect, canopy, elevation, season, and two-way interactions; elevation by canopy, elevation by season, aspect by canopy, and canopy by season.

There were no significant differences between selected instruments concerning consistency. However, the Soiltest instrument was found to be the most durable and least expensive.

Effect of Elevation, Aspect, Canopy, and Season on Soil Temperature Measurements for Soil Classification

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TABLE OF CONTENTS

I. INTRODUCTION 1

  Availability and Adequacy of Existing Data 1
  Objectives 2

II. ROLE OF TEMPERATURE IN SOIL CLASSIFICATION 4

  Methods of Soil Temperature Measurement and Predictability 6
  Environmental and Physical Factors Influencing Soil Temperature 9

III. FIELD OPERATIONS 12

  Site Selection and Description 12
  Experimental Design 15
  Instrument Calibration 18
  Data Collection 19

IV. DATA ANALYSIS 21

  Durability and Consistency of Instruments 28
  Effects of Aspect 36
  Effects of Canopy 42
  Effects of Elevation 44
  Effects of Season 49

V. IMPLICATIONS FOR SOIL CLASSIFICATION 61

VI. SUMMARY AND CONCLUSIONS 69

LITERATURE CITED 73

APPENDIX I 78

APPENDIX II 103

LIST OF FIGURES

Figure		Page
1	Instrument readings at 1000 feet southerly open	30
2	Instrument readings at 1000 feet northerly open	31
3	Instrument readings at 1000 feet southerly closed	32
4	Instrument readings at 1000 feet northerly closed	33
5	Main effect of aspect	38
6	Aspect by canopy interaction	39
7	Aspect by elevation interaction	40
8	Aspect by season interaction	41
9	Main effect of canopy	45
10	Canopy by aspect interaction	46
11	Canopy by elevation interaction	47
12	Canopy by season interaction	48
13	Main effect of elevation	50
14	Elevation by aspect interaction	51
15	Elevation by canopy interaction	52
16	Elevation by season interaction	53
17	Main effect of season	56
18	Season by aspect interaction	57
19	Season by canopy interaction	58
20	Season by elevation interaction	59
21	Aspect by canopy by season interaction	60

LIST OF TABLES

Table		Page
1	Combinations of site parameters studied	16
2	Location of sites	17
3	Analysis of variance table for Taxonomy seasons, including 610 meters	23
4	Analysis of variance table for alternate seasons, including 610 meters	24
5	Analysis of variance table for Taxonomy seasons, excluding 610 meters	25
6	Analysis of variance table for alternate seasons, excluding 610 meters	26
7	Difference between mean summer and mean winter temperatures	63
8	Average temperature °C of all sites at each elevation for each month	65
9	Temperature prediction model	67

EFFECT OF ELEVATION, ASPECT, CANOPY, AND SEASON ON SOIL TEMPERATURE MEASUREMENTS FOR SOIL CLASSIFICATION

I. INTRODUCTION

Soil temperature data have been collected for many reasons and under many conditions. Gounot (1973) studied the relationships between soil temperature and soil microbes/microbial processes. Palagin (1976) and Bocock et al. (1977) studied soil temperatures in an attempt to predict them from meterological data. Franxmeir et al. (196) examined the effects of slope aspect and slope position on soil temperatures. Jury and Bellantoun (1976a, b), Kimball et al. (1976), Cornish et al. (1973), Jones (1972) and Rodskjer (1975) each measured soil temperatures to characterize heat movement in soils. Soil temperature studies have been made in alpine soils (Rieger, 1973), in deciduous woodland soils (Bocock et al., 1977) and under field crops such as oats (Mackinnon, 1976). With the introduction of a new system of soil taxonomy in the United States (Soil Survey Staff, 1975), soil temperature has become an important consideration for soil classification as well.

Availability and Adequacy of Existing Data

Soil temperature data adequate for classifying soils according to current criteria (Soil Survey Staff, 1975) are often lacking. It's not that data don't exist, but because they were mostly taken for a variety of reasons other than classification, the records just aren't sufficient for taxonomic work. Smith et al. (1964) cite four principal reasons why existing data are inadequate for soil classification: because detailed site descriptions are not reported, observations are not from deep enough layers, the record was not kept throughout the year, or the methods of observation lead to biased results.

Much of the data on file at Oregon State University which are currently used to classify soils have been collected by the Soil Conservation Service, Bureau of Land Management, and the United States Forest Service. Many Land Grant Universities, including Oregon State University and the University of Nevada-Reno, have also studied soil temperatures for soil classification. Even these sources, however, suffer from two major limitations: the duration of temperature records is very short and often incomplete, and the data were not collected under comparable site conditions. Despite all these limitations, however, previous studies of soil temperature do provide much useful information about the methods and conditions under which the data were collected.

Objectives

The primary objective concerns specification of a standard procedure for obtaining soil temperature data adequate to classify soils at the family and great group levels. This is because of the inadequacy of existing data and the variation in methods and procedures currently being used by Soil Scientists today. In order to standardize the procedure, the effects which aspect, canopy, elevation, and season have on soil temperatures singly and in combination, will be evaluated. It has been widely demonstrated (Oswall and Sharma, 1977; Cabart, 1979; Toogood, 1979; McDole and Fosberg, 1974) that these factors have a major effect on soil temperature at various depths, but few people have tried to demonstrate their effects on the classification of soils at the family level. The durability and consistency of selected instruments will also be evaluated. The final objective is to test whether the months used by the Soil Survey Staff for calculating mean summer and winter temperatures are appropriate for this locality.

II. ROLE OF TEMPERATURE IN SOIL CLASSIFICATION

Classification of soils based on temperature occurs primarily at the family level (Soil Survey Staff, 1975; Buol et al., 1973). Soil families are constructed according to the effects that physical and chemical properties have on their response to management (Soil Survey Staff, 1975). Examples might include the response of soil temperature with the removal of natural vegetation or the length of growing season. Classification of soils based on temperature also occurs at the great group level, specifically cryic and tropo soils.

The Soil Survey Staff (1975) has established criteria for measuring soil temperatures and defining soil temperature regimes. Temperatures are to be taken at a depth of 50 cm (20 inches) or at a lithic or paralithic contact, whichever is shallower, and the readings are to be taken on or near the 15th of each month. The readings should not be made for at least 48 hours after a heavy rain. The average of the June, July, and August readings is to represent the mean summer soil temperature, the average of December, January and February readings is to represent the mean winter soil temperature, and the average of year around monthly or quarterly readings is to represent the mean annual soil temperature.

Once temperature data have been collected from a site, the soil can be classified into one of ten soil temperature regimes. The following are brief excerpts from the Soil Survey Staff (1975) defining the regimes:

Pergelic:	Soils have a mean annual temperature lower than 0°C.
Cryic:	Soils have a mean annual temperature higher than 0°C (32°F) but lower than 8°C (47°F). The mean summer temperature for well drained mineral soils is less than 8°C (47°F) if there is an O Horizon, less than 15°C if there is no O Horizon. Mineral soils that are periodically saturated in the summer must have mean summer temperatures less than 6°C (43°F) if there is an O horizon, less than 13°C (55°F) if there is no O horizon. Organic soils may or may not be frozen periodically, as long as they are cold all year but don't have permafrost.
Frigid:	The mean annual temperature is lower than 8°C (47°F), but it is warmer in the summer than a cryic soil.
Mesic:	The mean annual soil temperature is 8°C (47°F) or higher, but lower than 15°C (59°F).
Thermic:	The mean annual soil temperature is 15°C (59°F) or higher, but lower than 22°C (72°F).
Hyperthermic:	The mean annual soil temperature is 22°C (72°F) or higher.

Soils with the latter four mean annual soil temperatures and with a difference of less than 5°C between mean summer and mean winter soil temperatures have Isofrigid, Isomesic, Isothermic or Isohyperthermic regimes, respectively.

Methods of Soil Temperature Measurement and Predictability

The kinds of instruments that have been used to measure soil temperature include thermocouples (Carter and Ciolkosz, 1980; Schmidlin, 1981; Toogood, 1979; Jury and Bellantuon, 1976b), thermistors (Munn et al., 1978; Cabart, 1979; Bocock et al., 1977; Cornish et al., 1973; Rodskjer, 1975), maximum-minimum thermometers (Munn et al., 1978), and dial type thermometer probes (McDole and Fosberg, 1974; Franzmeir et al., 1969; Shanks, 1956). None of the studies cited made any comparisons among instruments or discussed the advantages or disadvantages of any particular instrument. All seemed to perform satisfactorily for the intended purpose.

Several investigators have obtained soil temperature data from depths shallower than 50 cm, for purposes which include evaluating the effect of drainage on soil temperatures (Jury and Bellantuon, 1976b), influence of vegetative cover on soil temperature (Munn et al., 1978; Toogood, 1979; Mottershead, 1971), evaluating the effects of soil temperature on microbial activity and root growth (Gounot, 1973; Richards et al., 1952), and estimating soil temperatures (Meikle and Treadway, 1979; Hank et al., 1971). Others (Soil Survey Staff, 1975; Cabart, 1979; Smith et al., 1964; Franzmeir et al., 1969; McDole and Fosberg, 1974) have collected temperature data from depths of 50 cm and greater, for soil classification purposes, and also for evaluating effects of vegetative cover on soil temperature. The 50 cm depth has been used in many studies because soil temperature at this depth is not influenced by diurnal variations in air temperature (Smith et al., 1964; Reimer and Shaykewich, 1980; van Wijk and deVries, 1963; Elford and Shaw, 1960). This is precisely the reason for specifying this depth for the purpose of soil classification (Soil Survey Staff, 1960, 1975). Classifiers consider the seasonal differences and annual averages more important than the daily effect.

Much work has been done to develop prediction equations for soil temperature. The simplest model uses air temperature to estimate soil temperature (Soil Survey Staff, 1975; Vann and Cline, 1975; Birse, 1980; Smith et al., 1964; Toy et al., 1978; Chang, 1975; Ouellet, 1973a, b; Rahn et al., 1967; Mueller, 1970; Bonham and Fye, 1970; Fye and Bonham, 1970). Bocock et al. (1977) point out, however, that comparisons of these works are "Often precluded because authors have failed to give adequate background information on site and methods or unambiguous statements of accuracy and precision of estimates." The Soil Survey Staff (1975) advises adding 1°C to the mean annual air temperature for estimating the mean annual soil temperature at 50 cm. This is in agreement with Vann and Cline (1975) and Birse (1980). Smith et al. (1964) and Chang (1975), however, concluded that soil temperatures may be more than 1°C warmer than air temperature in arid regions, areas with prolonged snow, or at high elevations. Mueller (1970) has even suggested adding or subtracting up to 7.2°C to the seasonal or annual mean air.temperature for soil temperatures at 20 cm depending on soil type, vegetation, aspect, slope, and altitude.

More complex models include additional meterological variables such as precipitation, number of rainy days, potential evapotranspiration, percent of possible sunshine, and snowfall in multiple regression models for predicting temperatures from 0 to 150 cm, with the degree of error greatest at the shallower depths (Rahn et al., 1967; Ouellet, 1973a,b). However, much work was required in determining many of the variables. Geographic variables like latitude, longitude, and elevation levels have been included in other models with good success (Arkley, 1972; Munn and Nielsen, 1979; Carter and Ciolkosz, 1980; Schmidlin, 1981).

Still other models tried to predict soil temperatures with fewer than twelve monthly readings (Munn et al., 1978; Carter and Ciolkosz, 1980; Soil Survey Staff, 1975; Smith et al., 1964; Rieger, 1973). Most commonly, four evenly spaced measurements throughout the year, on the 15th of March, June, September, and December were used to approximate the mean annual temperature. Carter and Ciolkosz (1980), however, used mid-January, April, July, and October to estimate the mean annual soil temperature, which resulted in better representation of the warmest and coolest seasons. Rieger used six evenly-spaced measurements, but suggested as few as four evenly-spaced measurements would also give a good estimate, as did the Soil Survey Staff (1975). Schmidlin (1981), however, showed that the error in predicting temperature decreases with increased number of months used for predicting.

Soil temperature models specifically designed to estimate seasonal temperatures are rare. Schmidlin (1981) predicted seasonal temperatures with some success. The Soil Survey Staff (1975) simply recommends using three measurements taken at 50 cm depth on June 15, July 15, and August 15, to approximate the mean summer soil temperature within 0.6°C of the mean summer temperature computed from daily readings, and using three measurements taken at a 50 cm depth on December 15, January 15, and February 15, to approximate the mean winter soil temperature. No one has determined whether the three months specified by the Soil Survey Staff (1975) to represent each season truly represent the warmest and coolest seasons in all geographical areas.

Environmental and Physical Factors Influencing Soil Temperatures

Environmental and physical factors that influence soil temperature include, climate, aspect, vegetation, presence of O horizon, elevation, and coarse fragments. Other factors include longitude, latitutde, and soil moisture. Many investigators (Cabart, 1979; Toogood, 1979; Munn et al., 1978) have tried to measure the effect any one of these factors might have on soil temperatures, but only a few (Gary, 1968; Shul'gin, 1978) have tried to measure the influence of interactions occurring between two or more of these factors.

Slope aspect may influence soil temperatures in several ways. Oswal and Sharma (1977) found that different orientations of ridge and furrow cultivation affected temperatures, with north-south orientations resulting in the warmest temperature. South-facing slopes are generally warmer than north-facing slopes (Macyk et al., 1978; Cantlon, 1953; Shul'gin, 1978; Rickard et al., 1971; Gary, 1968; McDole and Fosberg, 1974). They also warm up earlier in the spring, as indicated by earlier flowering of plants on south-facing slopes (MacHattie and McCormack, 1961). The effect of aspect however, varies with season. Temperature differences between north and south aspects are generally wider in the winter than in the summer (Macyk et al., 1978; Cantlon, 1953; Franzmeir et al., 1969; Shul'gin, 1978; Soil Survey Staff, 1975). Rickard et al. (1971) and Gary (1968), however, concluded that the differential may be greater in the summer. Franzmeir et al. (1969) attributed the seasonal effect to potential direct radiation. North aspects have strong summer maximums and very low levels during winter months. South aspects are much more uniform throughout the year.

The position of a site on a slope may also affect its temperature. Franzmeir et al. (1969) found that lower slope positions were cooler than higher positions. Lower sites are shaded by adjacent hills both in the morning and in the evening, and they tend to be wetter as well.

The influence of vegetative cover on soil temperatures has been studied widely. Cabart (1979) found that grass cover influenced only the temperature of the soil surface, whereas aspen cover of all densities decreased the soil temperature as much as 3.2°C to a depth of 90 cm. Specht (1958) and Hinds and Rickard (1968) found that soils under arid shrub communities were cooler than soils in unshaded areas, but that the difference was small below 30 cm due to lateral conduction of heat in the desert environment. Munn et al. (1978) showed that at high elevations temperature variation was greater in meadow soils than in forest soils. Soils that have an O Horizon are cooler in the summer than soils without, but are warmer during the winter than soils without O horizons, due to the insulating effect of the organic layer (Smith et al., 1964; Soil Survey Staff, 1975).

Studies dealing with elevation-temperature relationships all show that temperature decreases as elevation increases (McDole and Fosberg, 1974; Rieger, 1973; Schmidlin, 1981; Carter and Ciolkosz, 1980; Smith et al., 1964). Schmidlin (1981) has also established a relationship between latitude and soil temperatures in Nevada. He found that the mean annual soil temperature decreased .66°C for each degree increase in latitude, and that the influence was smallest in winter and largest in summer. Schmidlin (1981) also found that longitude influenced soil temperatures only during the autumn season.

The effects of soil texture and soil moisture content on soil temperature have been summarized by many authors (Franzmeir et al., 1969; McDole and Fosberg, 1974; Birmon, 1967). Smith et al. (1964) concluded that mean annual soil temperature was largely independent of texture and drainage, but was more affected by slope steepness and direction. Others (McDole and Fosberg, 1974; Franzmeir et al., 1969) found that poorly drained soils had cooler mean annual soil temperatures than adjacent well drained sites. Leonard et al. (1971), however, found that soils which were irrigated from June to August warmed faster and retained heat longer than similar non-irrigated soils.

III. FIELD OPERATIONS

The general procedure was to establish monitoring sites at enough different elevations to span the range of soil temperature regimes from mesic to cryic. At each elevation, sites were located on both northerly and southerly aspects, and within each aspect under full forest canopy and in an opening or clearcut. Temperatures were read monthly using four different instruments. Marys Peak, in the Oregon Coast Range was chosen as the general location for the study, because it meets all the criteria for site selection, and it is close enough to Corvallis to allow regular monthly readings.

Site Selection and Description

Marys Peak is nestled in the Oregon Coast Range approximately 12 miles southwest of Corvallis. At 1249 meters (4097 feet), it is the tallest mountain in the Coast Range. Mary's Peak consists of an erosion-resistant basaltic sill which intrudes bedded sandstones of the Middle Eocene Flournoy Formation, which in turn overlies the early Eocene Siletz River Volcanics (Lawrence et al., 1980; Baldwin, 1955, 1974; Snavely et al., 1968).

The annual precipitation ranges from 100 to 313 centimeters (40 to 125 inches). The higher amounts occur at the upper elevations, where snow is common. Bates and Calhoun (1969) may have best described the precipitation of the area in this brief excerpt:

> The usual movement of very moist maritime airmasses from the Pacific Ocean inland over the Coast Range produces near its crest some of the heaviest yearly precipitation (nearly all rain)

> in the United States. An annual total of almost 170 inches has been recorded, and one station situated in the Coast Range has established a period of record annual average near 125 inches. From the ridge crest of the Coast Range, approximately 3000 feet above sea level, there is a gradual decrease of rainfall down slope to the valley floor where annual totals average near 40 inches.

Timing of the precipitation is also of great importance as it affects both the type of vegetation occurring in the area and the rate of vegetative growth. Bates and Calhoun (1969) described the timing of precipitation as follows:

> Most of this precipitation in both the valley and its bordering mountain ranges occurs during the winter. In the mid-Willamette Valley about 70 percent of the annual total occurs during the five months November through March, while only 5 percent occurs during the three summer months.

Macyk et al. (1978) showed that precipitation also seems to modify soil temperatures. As the moisture content of the soil increases, so does its heat capacity, resulting in cooler soil temperatures in wetter sites during the summer.

The general soils maps from the soil survey reports of Benton County Area, Oregon (Knezevich, 1975) and Alsea Area, Oregon (Corliss, 1973) show the soils of the area consisting mostly of deep, well-drained gravelly clay loams, gravelly loams, and silty clay loams, and moderately deep and shallow well-drained gravelly loams. These soils include Typic Haplohumults, Typic Haplumbrepts, Andic Dystrochrepts, and Typic Dystrandepts. Parent materials include colluvium weathered from siltstone and sandstone, colluvium weathered from basaltic and intrusive rocks, and alluvial and colluvial materials derived mainly from basic igneous rocks but also from volcanic ash. All soils in the study area are said to have udic moisture regimes.

The vegetation of the Marys Peak area reflects the precipitation pattern. The major species occurring within the study area (Merkle, 1951) are Pseudotsuga Menziesii (Douglas Fir), Tsuga heterophylla (Western Hemlock), Thuja plicata (Western red Cedar), Abies Procera (Noble fir), Abies grandis (Lowland White Fir), Abies amabilis (Red Silver Fir), Acer Circinatum (Vine Maple), Oxalis oregana (Wood Sorrel), Gaultheria shallon (Salal), and Berberis Nervosa (Oregon Grape).

Merkle (1951) also described the relationships of vegetation to the various slopes of Marys Peak. The north slope is covered dominantly by Tsuga heterophylla, Abies procera, and Pseudotsuga Menziesii. Pseudotsuga is most common up to 762 meters (2500 feet), with Tsuga most abundant from 762 meters (2500 feet) to 1067 meters (3500 feet). Abies procera is abundant above 1067 meters (3500 feet). Thuja plicata is common on moist sites up to 1067 meters (3500 feet). Other species found on north slopes include Taxus brevifolia (yew), Acer circinatum (vine maples) and Salix scouleriana (willow). Oxalis oregana makes up most of the herbaceous layer, except for scattered patches of Gaultheria shallon and Berberis nervosa under Pseudotsuga.

East slopes up to 1067 meters (3500 feet) are covered predominantly with Pseudotsuga menziesii, with an understory composed mainly of Gaultheria shallon and Berberis nervosa. Abies procera is found above 1067 meters (3500 feet), and Acer circinatum can be found scattered throughout on east slopes.

On south and southeast slopes Pseudotsuga menziesii is most common up to 1067 meters (3500 feet). Abies procera is common above 1067 meters (3500 feet), and Acer circinatum is scattered throughout. The shrub layer is composed mostly of Gaultheria shallon and Berberis nervosa under the Pseudotsuga. Very little shrub layer occurs under the Abies Procera.

West slopes are very moist, and abundant stands of Tsuga heterophylla commonly occur above 305 meters (1000 feet). There is very little shrub layer occurring under the dense stands of Tsuga heterophylla.

Experimental Design

Specific combinations of site parameters studied on Mary's Peak are indicated in Table 1. Seven elevations at 152 meter (500 feet) intervals between 305 meters (1000 feet) and 1219 meters (4000 feet), were selected. Four sites, one for each combination of aspect and canopy cover, were located at each elevation except 455 meters (1500 feet) and 1219 meters (4000 feet).

There were no closed canopy conditions present at the 1219 meter (4000 foot) elevation, so it was not possible to locate closed sites at this level. The instruments which were intended for the 1219 meter (4000 foot) level were then installed at the 455 meter (1500 foot) elevation under closed canopy conditions. This was done more as a matter of curiosity to see the pattern of temperature variation between 305 and 610 meters, in the event that the data indicated a change from mesic to frigid temperature regime. Because of the gaps in data at these elevations, they will be left out of further analysis work.

Table 1. Combinations of Site Parameters Studied.

	Open Canopy		Closed Canopy	
Elevation (ft.)	North	South	North	South
1000	X	X	X	X
1500			X	X
2000	X	X	X	X
2500	X	X	X	X
3000	X	X	X	X
3500	X	X	X	X
4000	X	X		

Closed canopy was defined as consisting of at least 70 percent coniferous forest cover of middle age class or older on soils with O horizons. Open sites were located in clear cuts or natural openings within 183 meters (200 yards) of the closed site where possible. Open canopy soils lacked O horizons, either because they had not formed or because they had been destroyed during logging. Vegetation on the open sites was either missing or included one or more of the following major species: Acer circinatum, Oxalis oregana, Gaultheria shallon, and Berberis nervosa.

There were a total of twenty-four sites, of which twelve occurred on southerly aspects, and twelve on northerly aspects. Twelve had closed canopies and twelve had open canopies. Legal descriptions are given in Table 2.

Four instrument types were chosen for use in measuring temperatures. These were YSI Thermistor beads, YSI Thermistor probes, Weston

Table 2. Location of Sites.

Site	Location
305 Meters Southerly Open	SE¼ Sec.1 T.12S. R.7W.
305 Meters Southerly Closed	NE¼ Sec.1 T.12S. R.7W.
305 Meters Northerly Open	NW¼ Sec.1 T.12S. R.7W.
305 Meters Northerly Closed	NW¼ Sec.1 T.12S. R.7W.
457 Meters Southerly Closed	NW¼ Sec.2 T.13S. R.7W.
457 Meters Northerly Closed	NW¼ Sec.2 T.13S. R.7W.
610 Meters Southerly Open	SW¼ Sec.35 T.12S. R.7W.
610 Meters Southerly Closed	NE¼ Sec.3 T.13S. R.7W.
610 Meters Northerly Open	SW¼ Sec.15 T.12S. R.7W.
610 Meters Northerly Closed	NW¼ Sec.22 T.12S. R.7W.
762 Meters Southerly Open	SE¼ Sec.28 T.12S. R.7W.
762 Meters Southerly Closed	SE¼ Sec.28 T.12S. R.7W.
762 Meters Northerly Open	SE¼ Sec.34 T.12S. R.7W.
762 Meters Northerly Closed	NW¼ Sec.34 T.12S. R.7W.
914 Meters Southerly Open	NE¼ Sec.29 T.12S. R.7W.
914 Meters Southerly Closed	NE¼ Sec.29 T.12S. R.7W.
914 Meters Northerly Open	SW¼ Sec.34 T.12S. R.7W.
914 Meters Northerly Closed	SW¼ Sec.34 T.12S. R.7W.
1067 Meters Southerly Open	SE¼ Sec.20 T.12S. R.7W.
1067 Meters Southerly Closed	SE¼ Sec.20 T.12S. R.7W.
1067 Meters Northerly Open	SW¼ Sec.20 T.12S. R.7W.
1067 Meters Northerly Closed	SW¼ Sec.20 T.12S. R.7W.
1219 Meters Southerly Open	NW¼ Sec.28 T.12S. R.7W.
1219 Meters Northerly Open	NW¼ Sec.28 T.12S. R.7W.

Mirroband thermometers, and G-205 Soiltest thermometers. A YSI Model 425 C Tele-Thermometer was used to record readings from the two thermistor types. These instruments were chosen to cover a wide range in cost so that the durability and consistency of relatively inexpensive instruments could be compared to that of relatively expensive ones.

Instrument Calibration

Before data collection could begin, all the instruments had to be calibrated to be sure that all readings taken would be equivalent. Calibration was accomplished with the use of ice baths. A mercury laboratory thermometer was also used to confirm the 0°C readings. Small ice cubes and water were added to a plastic container and allowed to come to an equilibrium of 0°C. The instruments were then inserted into the ice bath, with special precaution not to allow the sensitive parts of the instruments to touch either the container or an ice cube. The laboratory thermometer was also inserted in this fashion to double check the temperature of the water. This is a system of calibration which can be easily performed in field offices, and was the reason for its use here.

All thermistor beads and probes were calibrated prior to installation. Because the thermistors were not adjustable, any significant deviation from 0°C found while using the ice bath could be applied as a correction to each month's readings. The Soiltest and Weston thermometers were calibrated each month. Any deviations present in the Soiltest instruments could be adjusted, whereas any deviations in the Weston instruments could be corrected for in the same way as with the thermistors. Adjustments seldom exceeded plus or minus 1°C.

Data Collection

One thermistor bead and one thermistor probe were installed at each site by excavating a hole one square meter in area and 0.6 meters (24 inches) deep. The probe was pushed into the soil at a depth of 50 cm (20 inches). Air pockets and cobbles were avoided as much as possible to insure the best possible contact with the soil. A nail was used to create a starter hole which could be used to insert the thermistor bead. The bead was pushed back into the soil avoiding air pockets and cobbles to attain the best contact possible. While back filling the soil to restore the original site, the thermistor leads together were zig-zagged up through the soil to minimize water running down the leads. Near the surface the remaining lead wires and the thermistor jacks were inserted into a 15 cm (6 inch) length of 2.5 cm (1 inch) diameter PVC pipe. The pipe was placed vertically in the ground so that only 2.5 cm (1 inch) was above the surface. PVC cap was placed over the exposed end to protect the leads from possible damage from rodents or weather.

Each month, at the time the thermistors were read, a separate hole was excavated to a 40.5 cm (16 inch) depth so that the Weston and Soiltest thermometers could be inserted down another 10 cm (4 inches) to attain the 50 cm (20 inch) desired depth. This hole was never located directly upslope from the thermistors to eliminate the possibility of downslope water movement to the thermistors. These holes were filled immediately after readings were taken and new ones dug at slightly different locations in succeeding months.

All readings were taken on or near the 15th of each month. The thermistor leads were read using the YSI Model C Tele-Thermometer. The Weston and Soiltest thermometers were each inserted into the soil at 2 different points in the hole to obtain an average value. Readings were rounded to the nearest degree F for the Soiltest, the nearest degree C for the Weston, and to the nearest half degree C for the thermistors. Readings were taken in this fashion for 16 months, starting June 15, 1980 and ending September 15, 1981 (Appendix I).

Approximately six hours were required to complete a set of observations, so that the time of day at which two different sites were read could differ by several hours. This was of no concern, however, because it has been shown that very little diurnal temperature change is present at the 50 cm depth (Smith et al., 1964; Reimer and Shaykewich, 1980; van Wijk and De Vries, 1963; Elford and Shaw, 1960). Readings were taken at least 48 hours after major storms, which is in accordance with the Soil Survey Staff (1975) guidelines.

Detailed profile descriptions were made in pits which were excavated at each site to 150 cm (60 inches) or to bedrock, if shallower. There were wide variations in soils between northerly and southerly aspects and as the elevation increased. This was expected and unavoidable because soils would naturally change as parent material, climate, and other factors change.

IV. DATA ANALYSIS

Complete data from all temperature measurements under all conditions are tabulated in Appendix I. Graphical relationships among the variables evaluated are illustrated in Figures 5 to 21. Results of the analysis of variance of the data are presented in Tables 3 to 6.

A number of methods were used in analysis of the data. Graphs showing various temperature interactions among the main site factors were started early in the study and updated every two months. The SIPS statistical package (Rowe and Brenne, 1981) was used to develop analysis of variance tables and a multiple regression model of the data, concerning the main factors and temperature interactions among the main site factors.

One analysis of variance table (Table 3) was constructed using data from 305 meters (1000 feet), 610 meters (2000 feet), 762 meters (2500 feet), 914 meters (3000 feet), and 1067 meters (3500 feet). Season as represented in this table was defined according to Soil Survey Staff (1975) guidelines, where June, July, and August represent summer, and December, January, and February represent winter. A second ANOVA table (Table 5) was also constructed by using these same seasons but without data from the 610 meter level. The temperatures recorded at the 610 meters southerly open site were extremely warm, which was determined to be the direct result of soil condition. It was shown by both comparing the soil profile descriptions (Appendix II) with soils as mapped in the Benton County area Soil Survey report (Knezevich, 1975) and by on site investigations that the soil at the site was not representative of the majority of deep gravelly silt loams occurring in the region of 610 meters. The soil at the site was only 50 cm (20 inches) deep and skeletal. Thus, to evaluate the impact of this site, two analysis of variance tables were developed, with and without the 610 meter level.

These tables indicate that the effect of elevation is compounded by interactions with other factors (Tables 3 and 5). Some of these interactions, however, appear to be related solely to unusually high temperatures at the 610 meter southerly open site. Because the soil at this site may not represent typical soil conditions throughout the region at 610 meters, the interaction may be more the result of a quirk in the sample than a real effect. Re-analysis of the data without any of the data from the 610 meter level indicates that some of the interactions lose their statistical significance (Table 5).

Additional analysis of variance tables (Tables 4 and 6) were also developed after re-arranging the seasons to account for any possible lag time occurring between air temperature and soil temperature. The alternate season defined summer as July, August and September and winter as January, February and March. To evaluate the impact of the soil condition at the 610 meter southerly open site, two tables were developed, with and without the 610 meter level.

Each variable, acting independently, had a statistically significant effect with or without 610 meter data (at the .05 level), and using either set of seasons (Tables 3 to 6). This is not surprising, because most of the prior studies of soil temperature observed similar effects (Cabart, 1979; Toogood, 1979; Munn et al., 1978; Gary, 1968; Shul'gin, 1978). The effects of each variable, however, are

Table 3. Analysis of Variance Table for Taxonomy Seasons, Including 610 Meters.

ANOVA FOR TAXONOMY SEASONS, WITH 610 METERS.

Source of Variation	DF	Mean Square	F-Value	P-Value
Elevation	4	33.1	194.0	.0000
Aspect	1	33.6	197.2	.0000
Canopy	1	19.4	113.6	.0000
Season	3	151.5	888.0	.0000
Elevation x Aspect	4	1.2	7.1	.0002
Elevation x Canopy	4	1.3	7.7	.0001
Aspect x Canopy	1	20.8	121.9	.0000
Elevation x Season	12	.74	4.4	.0002
Aspect x Season	3	.57	3.3	.0276
Canopy x Season	3	8.5	49.5	.0000

Table 4. Analysis of Variance Table for Alternate Seasons, Including 610 Meters.

ANOVA FOR ALTERNATE SEASONS, WITH 610 METERS.

Source of Variation	DF	Mean Square	F-Value	P-Value
Elevation	4	33.2	189.9	.0000
Aspect	1	31.5	179.9	.0000
Canopy	1	17.9	102.8	.0000
Season	3	126.9	725.8	.0000
Elevation x Aspect	4	1.2	6.6	.0003
Elevation x Canopy	4	1.2	6.8	.0002
Aspect x Canopy	1	19.2	109.7	.0000
Elevation x Season	12	.66	3.8	.0006
Aspect x Season	3	.35	2.0	.1279
Canopy x Season	3	9.5	54.5	.0000

Table 5. Analysis of Variance Table for Taxonomy Seasons, Excluding 610 Meters.

ANOVA FOR TAXONOMY SEASONS, WITHOUT 610 METERS.

Source of Variation	DF	Mean Square	F-Value	P-Value
Elevation	3	35.9	299.6	.0000
Aspect	1	18.2	151.4	.0000
Canopy	1	9.3	77.7	.0000
Season	3	114.9	958.2	.0000
Elevation x Aspect	3	.18	1.5	.2371
Elevation x Canopy	3	.44	3.7	.0221
Aspect x Canopy	1	12.2	101.6	.0000
Elevation x Season	9	.79	6.6	.0000
Aspect x Season	3	.35	2.9	.0477
Canopy x Season	3	5.8	48.2	.0000

Table 6. Analysis of Variance Table for Alternate Seasons, Excluding 610 Meters.

ANOVA FOR ALTERNATE SEASONS, WITHOUT 610 METERS.

Source of Variation	DF	Mean Square	F-Value	P-Value
Elevation	3	35.9	322.4	.0000
Aspect	1	16.8	150.2	.0000
Canopy	1	8.6	77.4	.0000
Season	3	96.9	868.8	.0000
Elevation x Aspect	3	.13	1.2	.3417
Elevation x Canopy	3	.37	3.4	.0304
Aspect x Canopy	1	11.4	102.1	.0000
Elevation x Season	9	.74	6.6	.0000
Aspect x Season	3	.37	3.3	.0319
Canopy x Season	3	6.5	58.6	.0000

not simple and straight forward, for in many cases there are statistically significant two-way interactions (at the .05 level). This implies that their effect changed as levels of other factors changed. Both main effects and their interactions will be discussed in more detail under the titles of the main effects in the sections that follow.

The analysis of variance tables of the alternate seasons (Tables 4 and 6) were much like those for the taxonomy seasons (Tables 3 and 5). All main effects were significant with or without 610 meter data. The alternate season table excluding 610 meter data was also in agreement with the taxonomy season table with respect to which interactions were significant. The alternate season table including 610 meter data was also in agreement except for the aspect by season interaction. This interaction was significant using taxonomy seasons (Table 3) but was not when using alternate seasons (Table 4), indicating that when using alternate seasons the effect of aspect does not change with change in seasons. Because there was only one difference between taxonomy seasons and alternate seasons, the following discussions will be based on graphs and analysis of variance tables for taxonomy seasons.

In order to discuss the main effects and interactions, the durability and consistency of instruments used were evaluated. This was done in order to base discussions on data from the most durable and consistent instrument.

Durability and Consistency of Instruments

Durability and consistency of instruments is of utmost importance when undertaking long-term studies of soil temperatures. The purpose and accuracy of the needed measurements, and the field conditions under which measurements are to be taken are important criteria in the selection of appropriate instruments. Therefore, the durability and consistency of four instrument types were evaluated in relation to soil conditions and design of instruments.

The Soiltest metal thermometers were the most durable of the four instruments. They held up well under all field conditions, which included wet, dry, and skeletal soils. They were strong enough so that pressure could be applied to force them into dry soils, and they also proved to be suitable for use in skeletal soils. One of these instruments did fail, but there was no apparent reason why.

The Weston Mirroband thermometers were also suitable for use in wet or skeletal soils. They were much more susceptible to bending from pressure applied while pushing them into very dry soils. This bending resulted in one of two things: bending some place on the stem weakened it for further use; whereas, bending at the junction between the stem and dial resulted in the dial needle sticking, and therefore not reacting to changes in temperature.

The durability of the thermistors was quite varied. Neither the pointed metal tubular probe or the general purpose vinyl bead were affected by weather conditions. However, soil conditions did pose some problems for the vinyl bead. Good soil contact was difficult to achieve, especially in dry or skeletal soils. The pointed metal probe was much better suited for these soil conditions. It could be pushed into the soil, whereas with the flexible vinyl bead, a starter hole made with a nail was required before insertion into the soil.

The major problem with the thermistors was that of rodent damage. Six times during the 16-month study burrowing rodents intercepted the leads and cut them off. This could have been eliminated by extending the PVC pipe to a depth of twenty inches. The original pit would need to be wider, so that the sensitive tips of the thermistors could be installed in one side of the pit, the leads laid parallel to the bottom and up through the pipe at the opposite side. Locating the PVC pipe at the opposite side of the pit would eliminate the possibility of moisture flowing down the pipe and leads, thus interfering with the critical recording area.

Data from all instruments under all site conditions at 610 meters were plotted to evaluate the consistency of the instruments with respect to each other (Figures 1 to 4). The thermistor bead and the thermistor probe read essentially the same throughout the year. The only difference between the Weston Mirroband and Soiltest metal thermometers was that the Weston readings were slightly higher during the summer peaks, with no apparent reason. During the remainder of the year both instruments were in very close agreement. The variability between instruments during the first summer was attributed to human error in rounding off the readings because many people were helping this first summer. During the rest of the study one person was in charge of recording temperatures, so that better consistency was achieved in rounding off of readings. When averaged over the

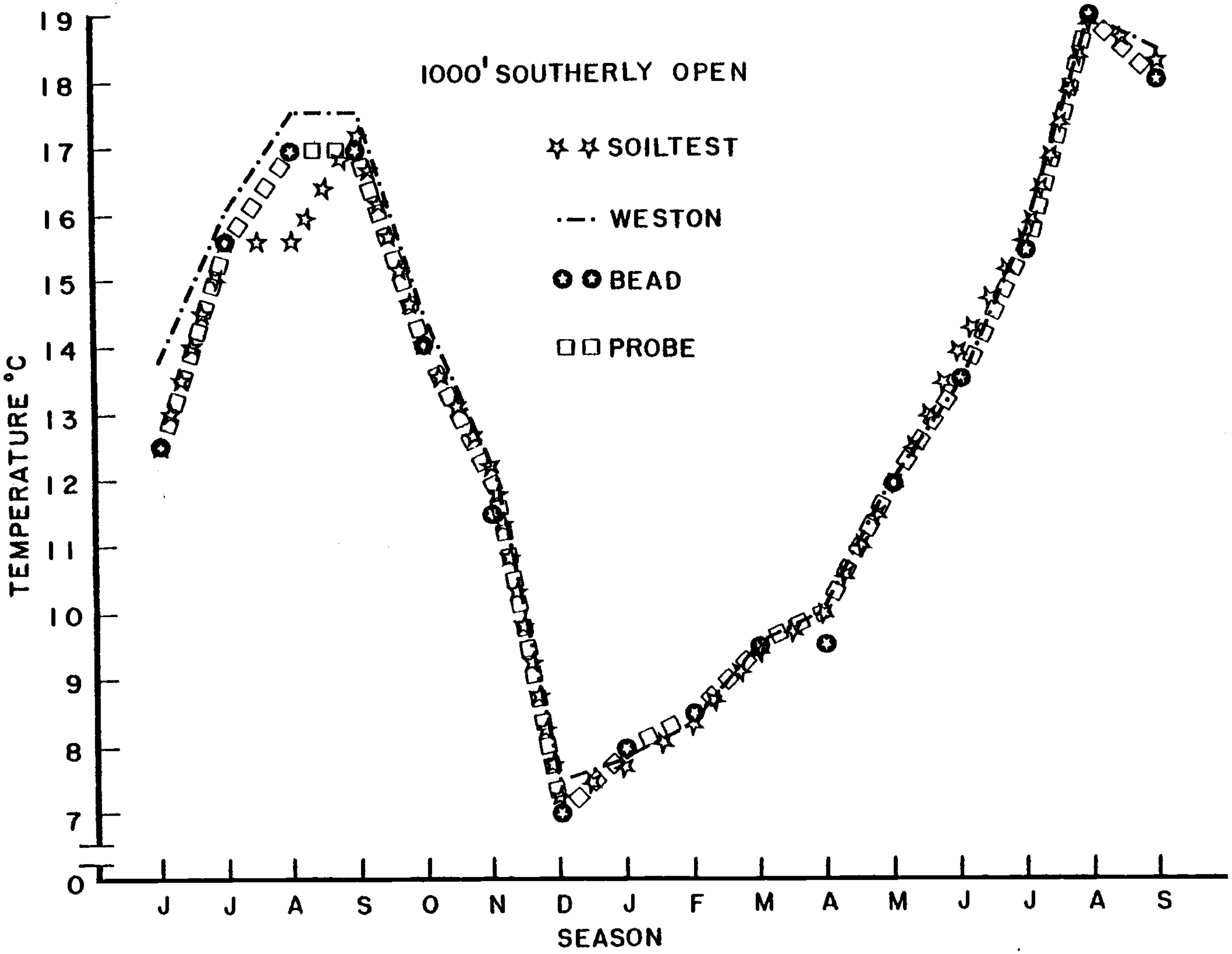

Figure 1. Instrument readings at 1000 feet southerly open

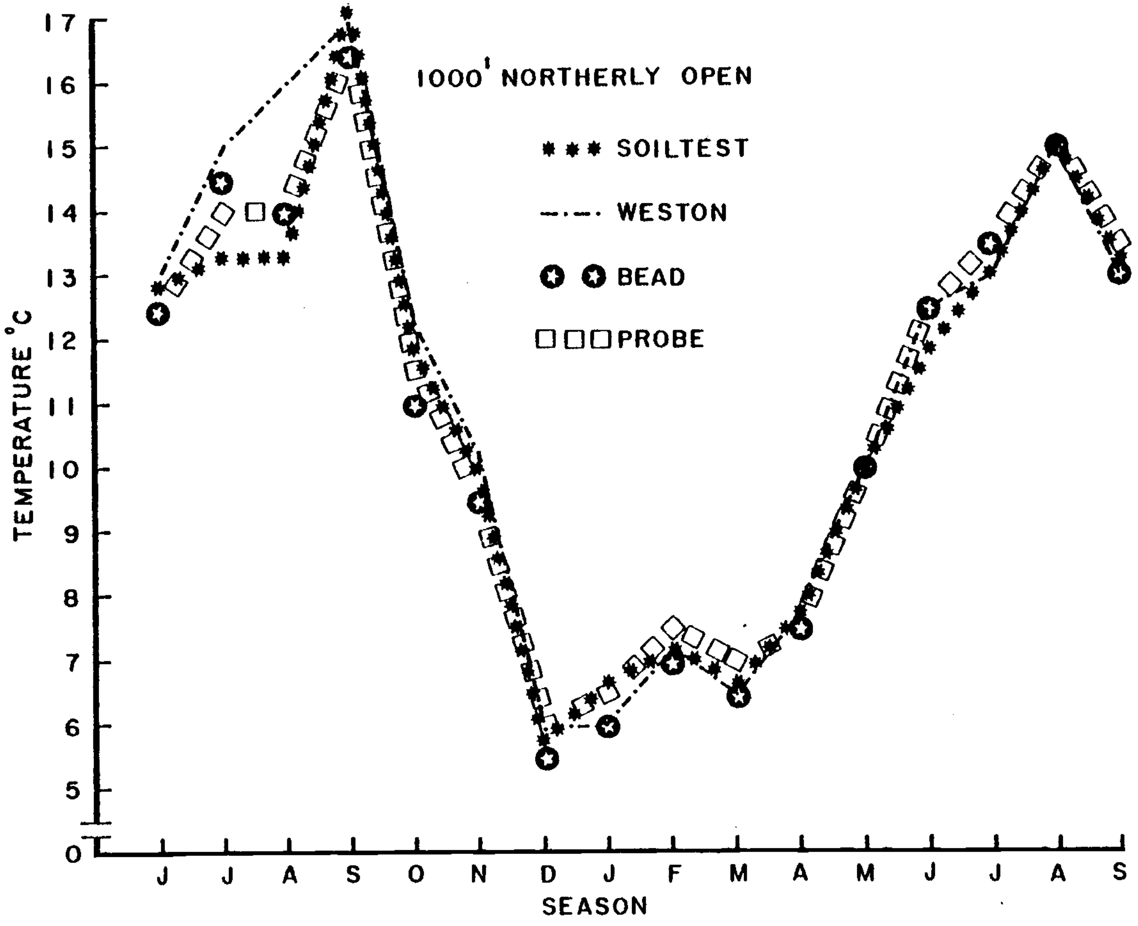

Figure 2. Instrument readings at 1000 feet northerly open

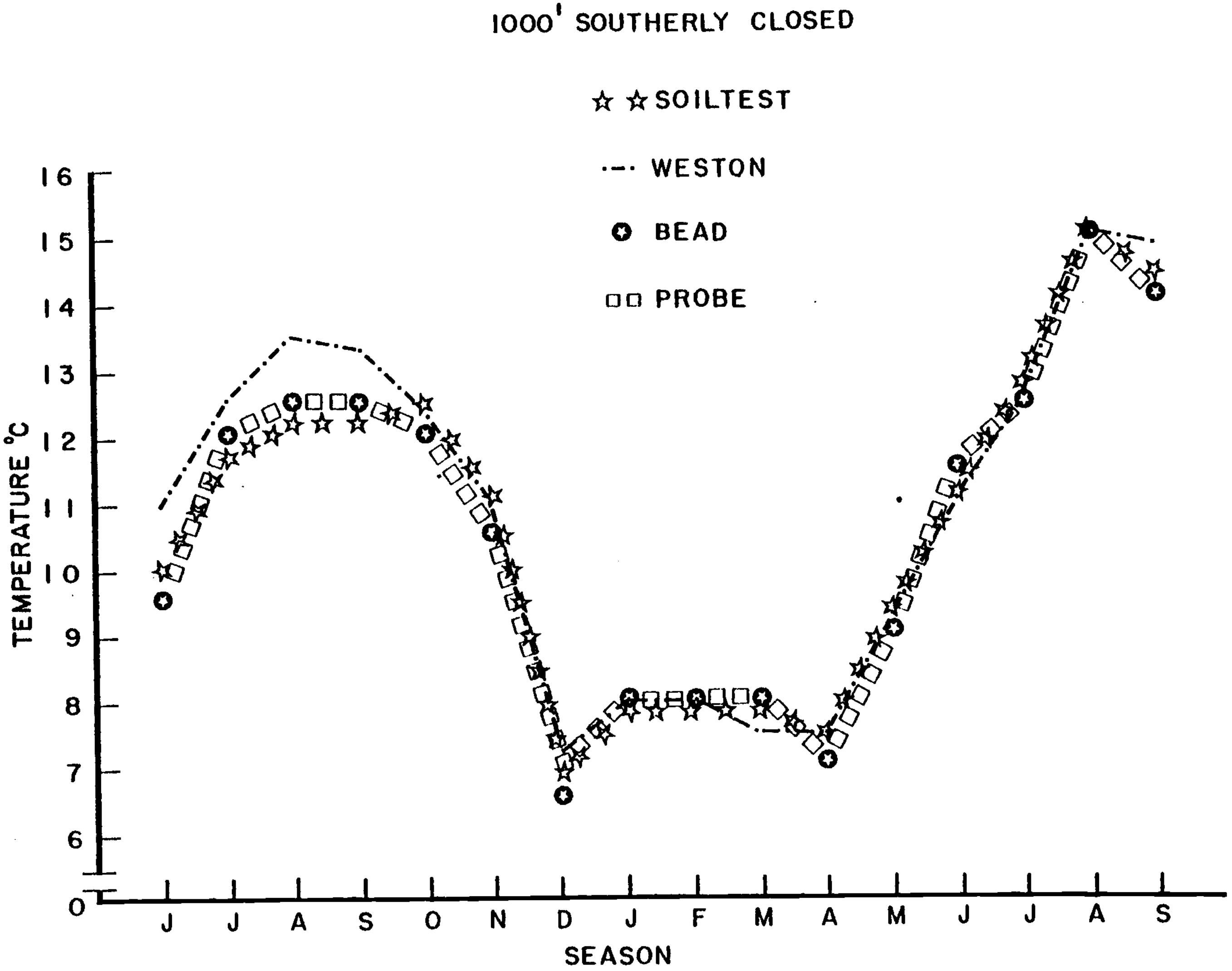

Figure 3. Instrument readings at 1000 feet southerly closed

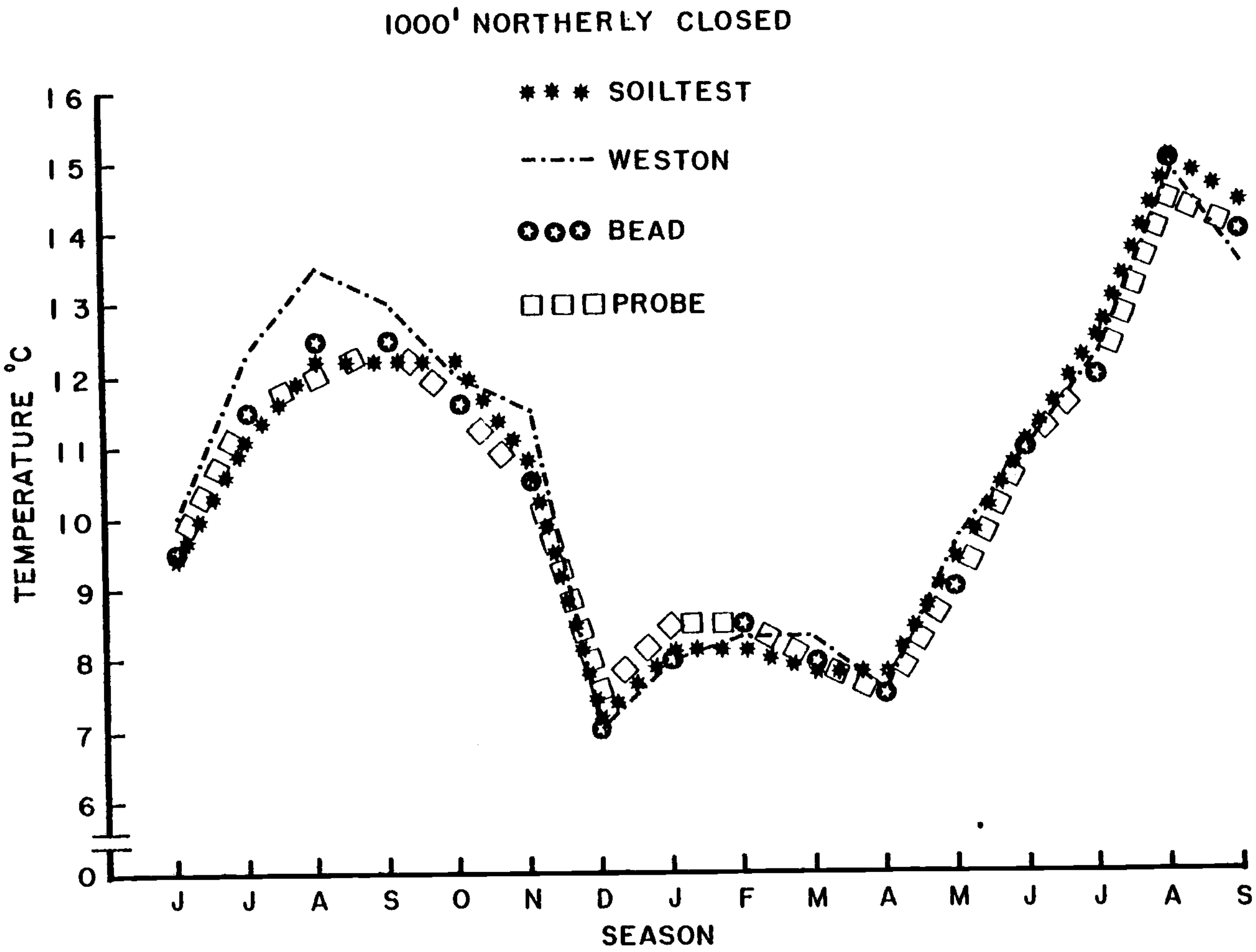

Figure 4. Instrument readings at 1000 feet northerly closed

whole year there was very little difference in consistency between instruments under any site conditions. Consequently, only the data from the thermistor probe are presented in the graphs and analysis of variance tables that follow in the remainder of this chapter.

The Soiltest metal thermometers were by far the cheapest ($17.80), but the time involved and soil disturbance created with this instrument may outweigh the cost advantage, especially in long-term studies. There was approximately an added five minutes involved each month in digging holes for measurements at each site, which would only create problems if great numbers of sites were to be recorded. Soil disturbance from digging would only create problems if the sites were to be maintained over an extended period of time. These same problems also would be encountered with use of the Weston Mirroband instruments, which cost $31.50 each. Therefore, if cost is a major factor in instruments, selection of the Soiltest metal thermometer would be recommended because it is both cheaper and more durable than the Weston Mirroband.

If great numbers of sites are to be recorded, and if time and soil disturbance are of greater concern than cost, then either type of thermistor would be satisfactory. The vinyl probe is considerably cheaper at $26.50 than the metal tubular probe at $60.00. Therefore, with the exception of the inconvenience of assuring good soil contact during initial installation, it would be the top choice. There is, however, the risk of rodent damage and human vandalism involved with use of the permanently installed thermistors. Therefore, the use of the twenty inch PVC pipe as described earlier and the location of sites away from the main flow of human traffic is advisable.

The added expense of using thermistor probes or beads could be offset with savings of labor cost. If the following assumptions are made; labor cost of $10.00 per hour, that an average of five minutes are saved at each site with use of the thermistors, and that 24 sites are used, then 2 hours would be saved each month, for a total labor savings of $240.00 a year. Equipment costs were based on 1982 prices from various sellers. Then initial equipment and labor expenses incurred if thermistor beads are used at all 24 sites include 24 thermistor beads $660.72, 13 meters (48 feet) of .5 inch PVC pipe $6.72, 24 PVC caps $6.00, YSI Tele-Thermometer $367.00, and labor of installation $120.00 for a total of $1160.44. The intial equipment and labor expenses incurred if thermistor probes are used at all 24 sites would include, 24 thermistor probes $1452.72, 13 meters (48 feet) of .5 inch PVC pipe $6.72, 24 PVC caps $6.00, YSI Tele-Thermometers $367.00, and labor for installation $120.00, for a total of $1952.44

If the cost of the Soiltest instrument of $17.80 is subtracted, then the total added initial expense of using the thermistor bead would be $1142.62, and for the thermistor probe it would be $1934.64. Therefore, if it is assumed that no equipment breakdowns occur and that $240.00 of labor expenses are saved per year it would take approximately 4.75 years to offset the added equipment expense incurred from the thermistor beads with labor savings, and approximately 8 years to offset the added equipment expense incurred from using thermistor probes with labor savings. As labor expenses rise this time period would be reduced.

Effects of Aspect

On the average, southerly aspects are significantly warmer than northerly aspects, with or without the 610 meter data (Figure 5; Tables 3 and 5). The effect is well documented by numerous investigators (Franzmeir et al., 1969; McDole and Fosberg, 1974; Smith et al., 1964; MacHattie and McCormack, 1961; Cantlon, 1953; Macyk et al., 1978; Soil Survey Staff, 1975). Southerly aspects receive more direct solar radiation.

There is a significant interaction between aspect and canopy, with or without 610 meter data (Tables 3 and 5). This means that the effect of aspect is not the same under both canopy conditions. The interaction is illustrated in Figure 6 by the lack of parallelism of the two lines. This graph shows that aspect has very little effect under closed canopies, but it has very pronounced effect under open canopies. Apparently full vegetative canopy insulates the soil surface so that the soil itself on southerly aspects receives little more direct radiation than the soil on northerly aspects. Soils on southerly aspects without forest canopies have no protection from direct solar radiation, and they respond by heating up considerably more than similar soils on northerly slopes.

The effect of the aspect by elevation interaction (Figure 7) is significant if data from 610 meters are included (Table 3), but it is not significant if those data are excluded (Table 5). All the lines in Figure 7 are parallel except the one for 610 meters. This anomaly appears to be related solely to unusually warm temperatures at the 610 meter-southerly-open site. The soil at this site may not represent soils typically occurring in the region at this level, and the interaction may be the result of the sample and not a real effect. After removal of the 610 meter data, the lines in Figure 7 would be essentially parallel, and the interaction is no longer significant (Table 5).

The effect of the aspect by season interaction is significant with or without data from 610 meters (Figure 8; Tables 3 and 5), although only slightly when including 610 meter data (Table 5). On southerly aspects, the fall season is the warmest, summer is slightly cooler, and spring and winter are the same. On northerly aspects, the summer season is the warmest, fall is slightly cooler, winter is much cooler than fall, and spring has the coldest temperatures. This interaction suggests that soils reach their warmest point on northerly aspects before southerly aspects, and that soils reach their coldest level on southerly aspects before northerly aspects. Franzmeir et al. (1969) attribute this to potential direct radiation. Southerly aspects receive higher levels of direct radiation later in the fall than northerly aspects. Also, levels of direct radiation start to increase first on southerly aspects, thus southerly aspects reach their highest temperature at 50 cm depths later in the fall, and reach their lowest temperature earlier in the spring than northerly aspects.

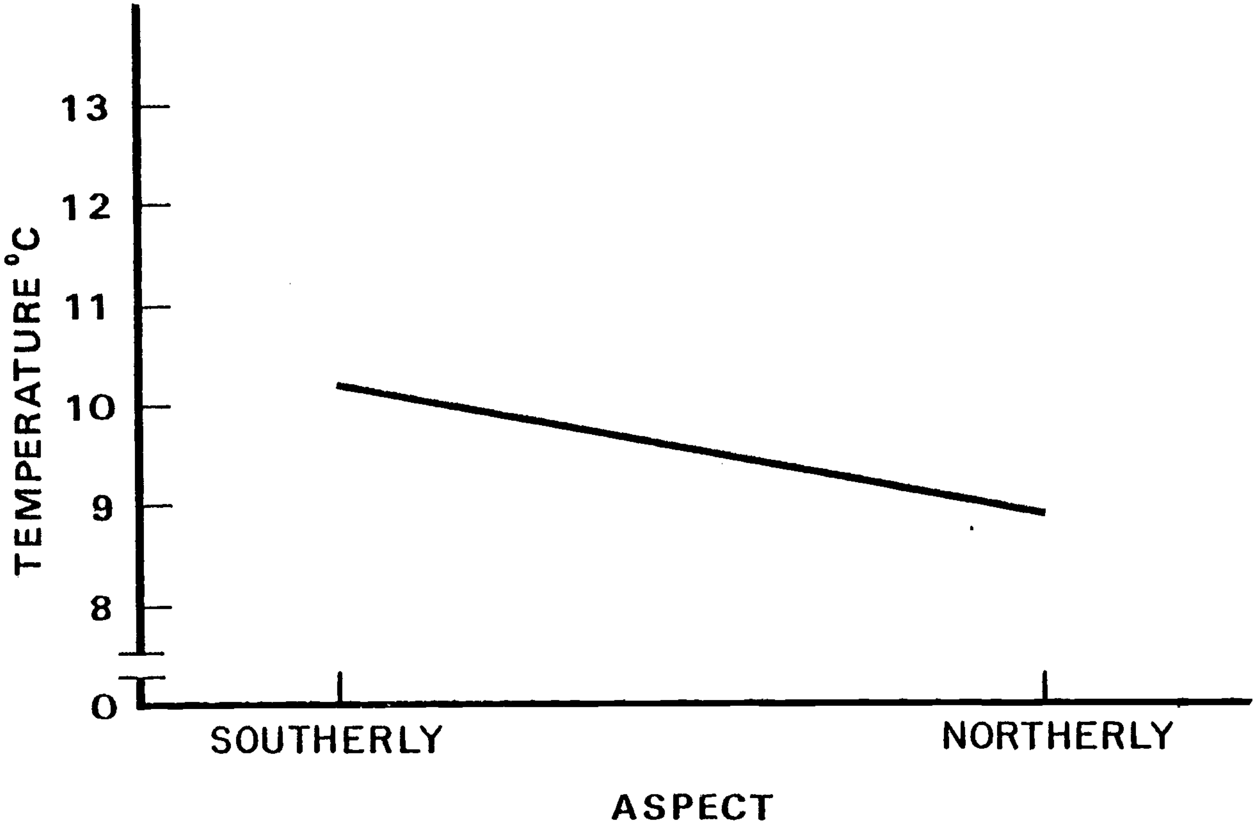

Figure 5. Main effect of aspect

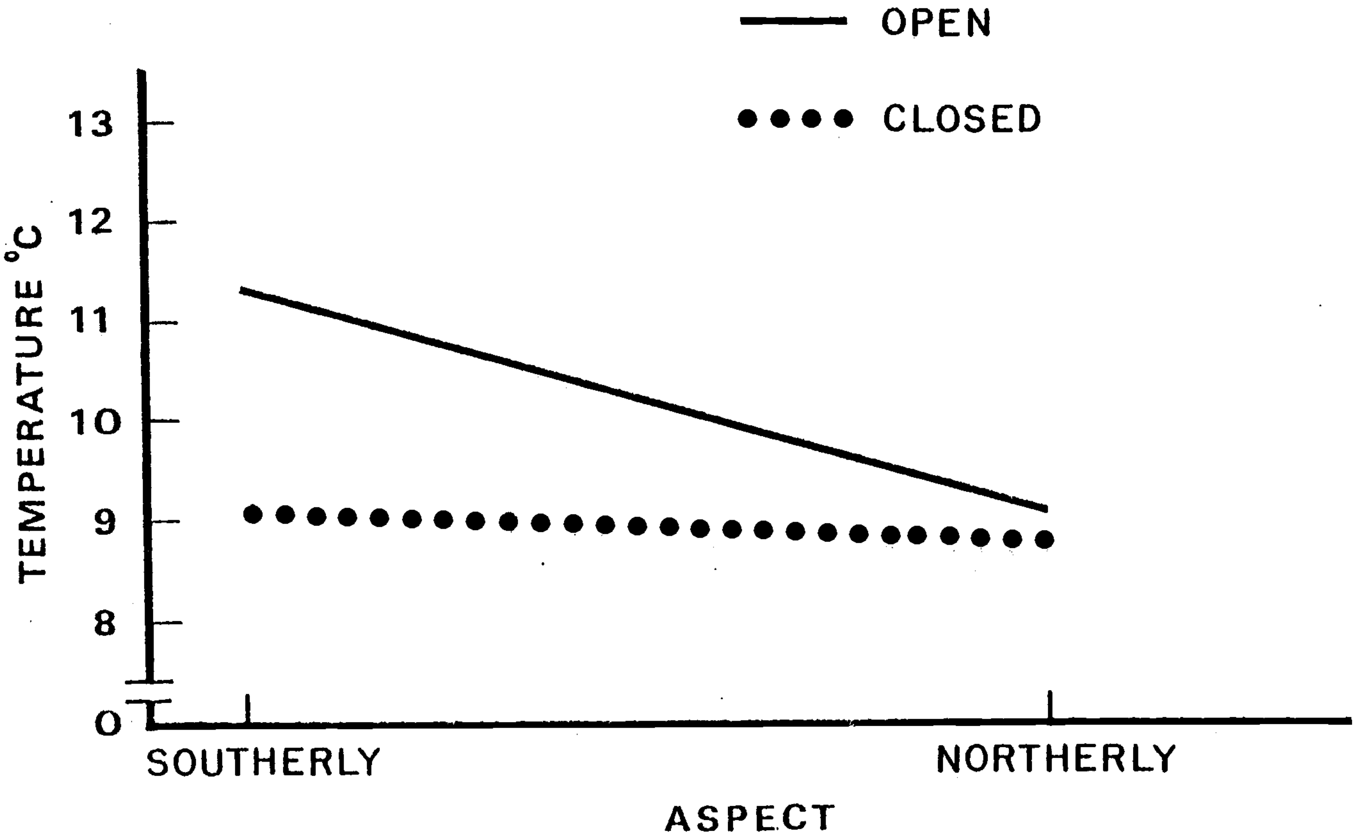

Figure 6. Aspect by canopy interaction

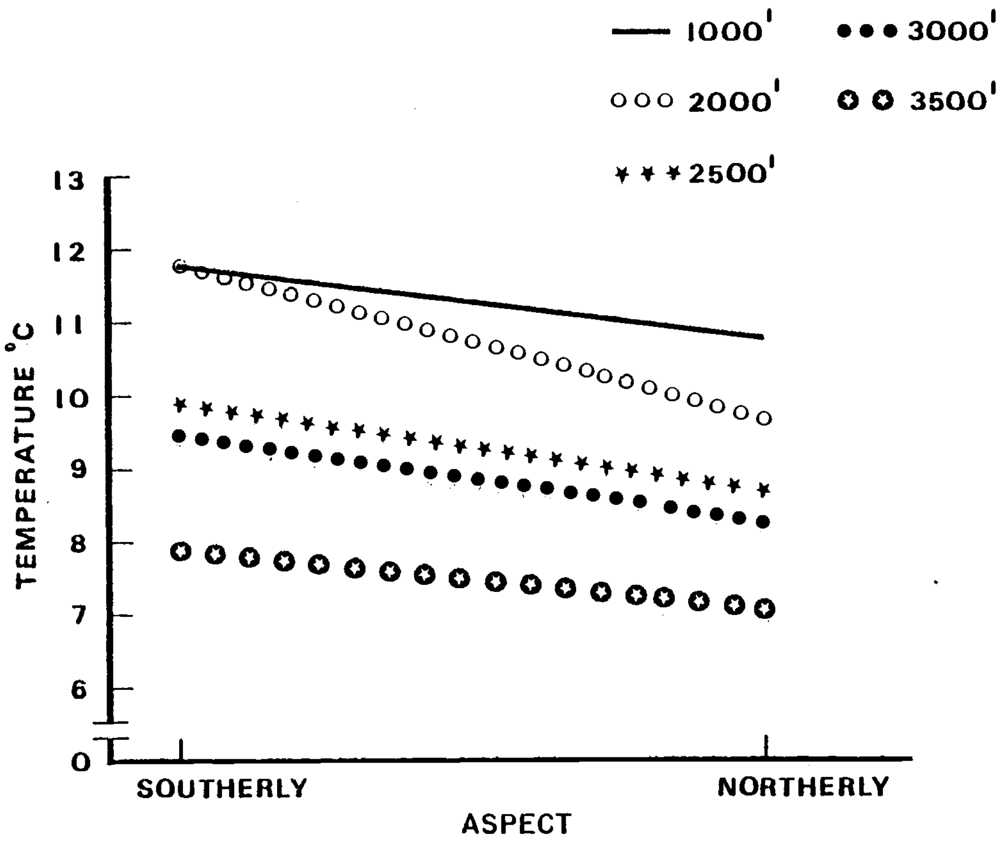

Figure 7. Aspect by elevation interaction

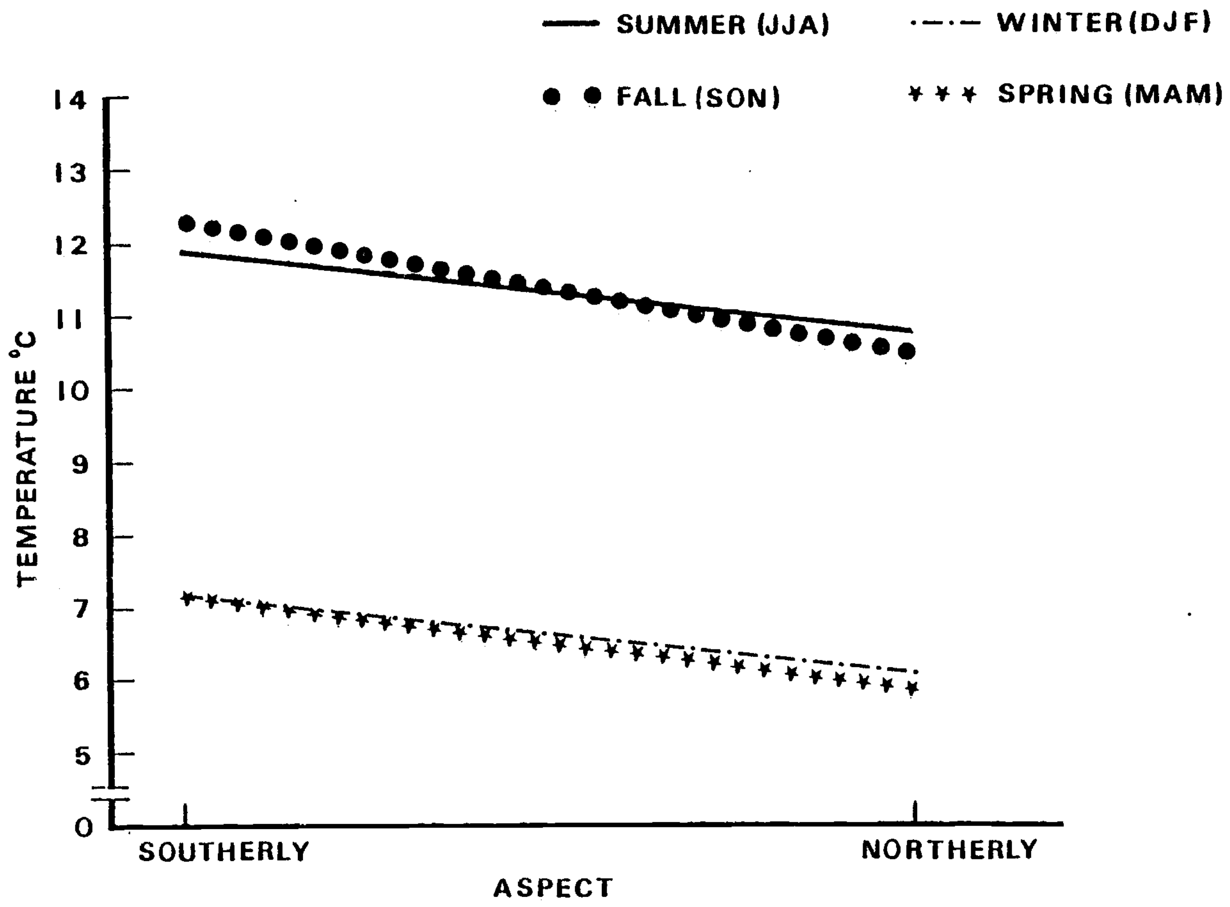

Figure 8. Aspect by season interaction

Effects of Canopy

The canopy effect is manifest in reduced temperature under closed canopies with or without data from 610 meters (Figure 9; Tables 3 and 5). The average temperature of all closed canopy sites is 1.3°C lower than the average temperature of all open canopy sites. Numerous investigators (Franzmeir et al., 1969; Cabart, 1979; Toogood, 1979; Smith et al., 1964; Soil Survey Staff, 1975) have shown that there is an insulation effect under the closed canopy. This results in less solar radiation reaching the soil surface, thus keeping the soil cooler.

Tables 3 and 5 show that the interaction between canopy and aspect, with or without 610 meter data, is statistically significant. The character of the interaction is evident from Figure 10. Canopy has virtually no effect on northerly aspects (0.2°C), but a very pronounced effect (2.2°C) on southerly slopes. Thus the insulating effect is important only when the soil is exposed to large amounts of direct solar radiation, as on southerly aspects.

The canopy by elevation interaction is also statistically significant with or without 610 meter data (Tables 3 and 5). Figure 11 illustrates this interaction. Much of the interaction appears to be due to the unusually warm site at 610 meters. Close examination of Figure 11, however, reveals that even without those data there is a slight difference in slope of the various lines. This difference is small and may not have much practical significance. The explanation may be that at lower elevations there is a wider range of temperature because it gets warmer in summer, so that the insulating effect of canopy is more pronounced at low elevations. It may also be that the only reason for statistical significance is the steeper slope of the 1000 foot line, and that the very slight differences in slope among the 2500, 3000, and 3500 foot lines are not significant at all.

The interaction between canopy and season is pronounced (Figure 12) and is statistically significant with or without 610 meters (Tables 3 and 5). Figure 12 shows that the effect is essentially the same for fall and spring; i.e. the closed canopy is cooler by about the same magnitude. The trend is the same but more pronounced during the summer. This is the period of most intense direct solar radiation, and it shows up as a warmer temperature under open canopy and a cooler temperature under closed. Without insulation (open), the soil temperature responds quickly to direct radiation, and the warmest temperature is in the summer. With insulation, the temperature is not only cooler, but it takes longer for the soil to respond. Thus, there is a lag, such that the warmest temperature under closed canopy is delayed by one season.

The insulating effect is even more pronounced in the winter, when the effect of canopy is just the opposite of the other three seasons. Again, the open canopy, lacking insulation, responds quickly to ambient temperature. Loss of heat by radiation from the soil also occurs more readily. Hence the coldest temperature in the soil occurs when the air is coldest as well. Insulation by closed canopies delays the temperature extremes by one season just as it does on the warm end of the scale. Thus, spring is the coldest season for soil temperatures, rather than winter. Numerous investigators (Munn et al., 1978; Cabart, 1979; Franzmeir et al., 1969; Toogood, 1979) have noted this lag time, and have attributed this to the forest canopy and litter layers intercepting solar radiation thus delaying the warming period. Thus, open sites are warmest in the summer and coolest during the winter, whereas closed sites are a season behind, with fall the warmest and spring the coolest.

Effects of Elevation

It is very clear that soil temperatures decrease as elevation increases, with or without the 610 meter level (Tables 3 and 5; Figure 13). The effect is well known and understood, and has been documented by numerous investigators (Carter and Ciolkosz, 1980; McDole and Fosberg, 1974; Smith et al., 1964; Schmidlin, 1981).

An interaction between elevation and aspect is illustrated in Figure 14. This figure includes the data from 610 meters, and shows that the effect of elevation is indeed the same for both aspects except for the 610 meter level. If those data were excluded, the two curves in Figure 14 would be essentially parallel, and the interaction is no longer significant (Table 5). The soil properties at the site, particularly the high content of rock fragments, cause the soil to be unusually warm. If this soil condition is widespread, then the interaction is real and important. If, however, the site happened to fall on a very minor inclusion, then the interaction is probably not typical for the area as a whole.

The interaction between elevation and canopy is statistically

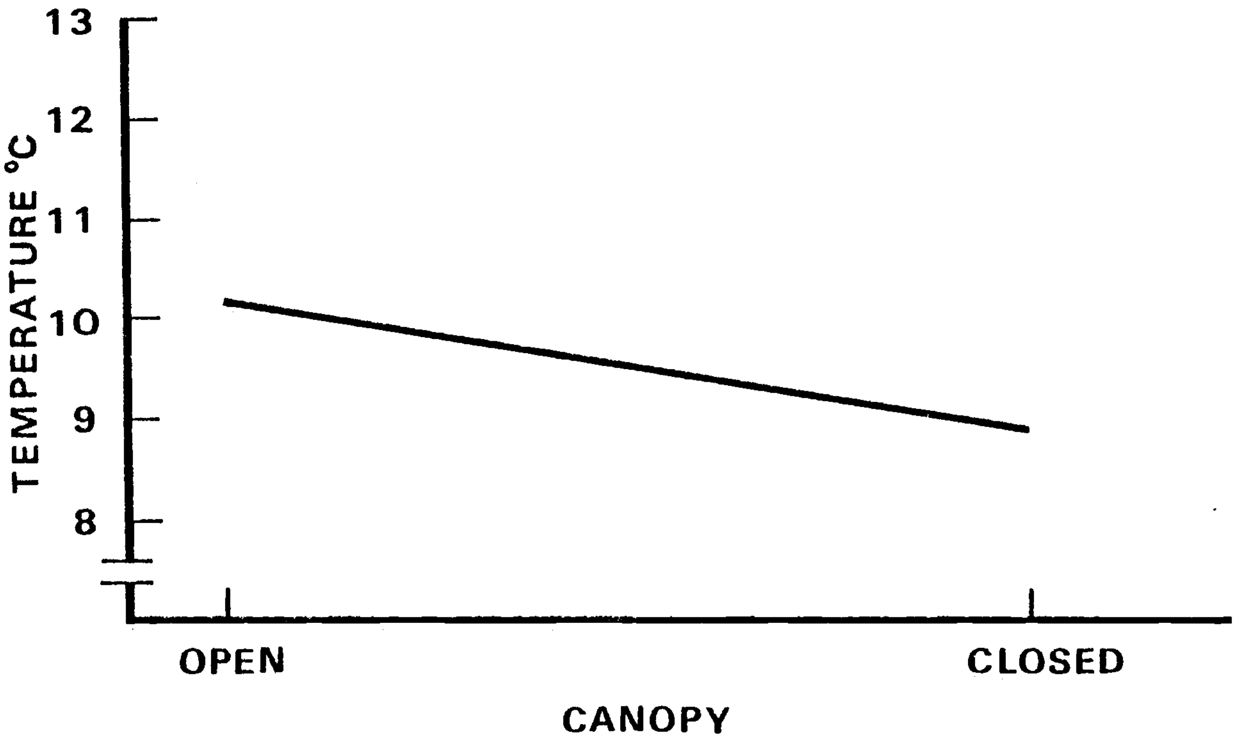

Figure 9. Main effect of canopy

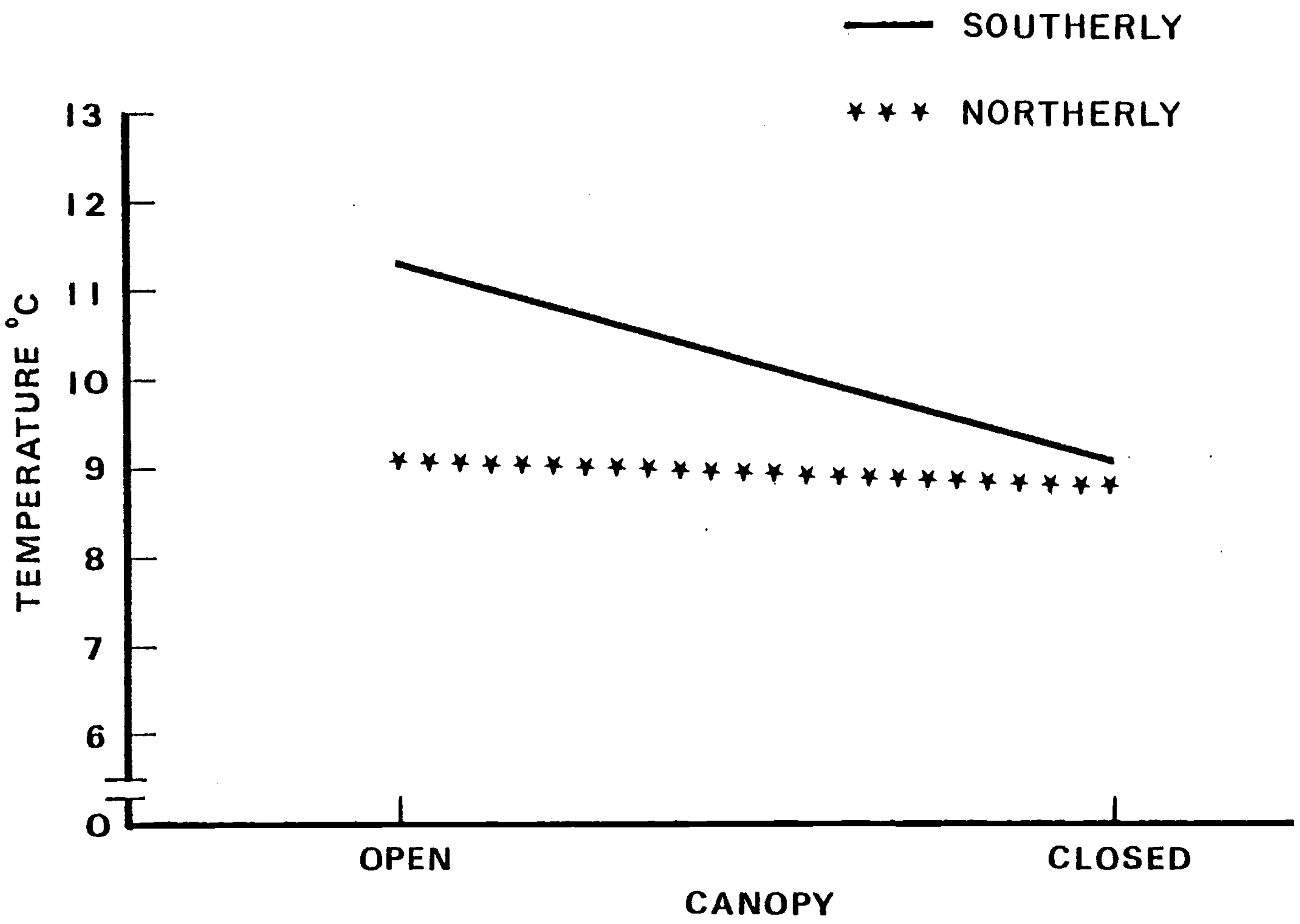

Figure 10. Canopy by aspect interaction

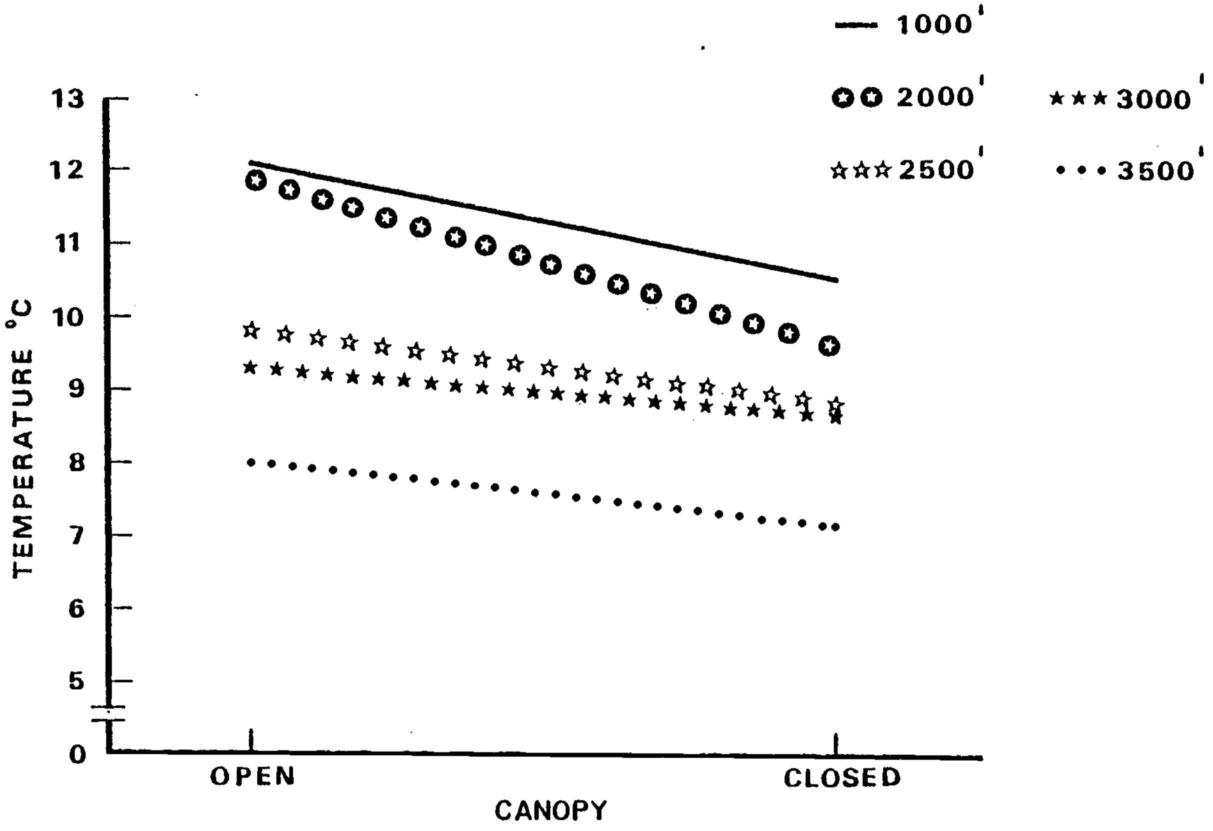

Figure 11. Canopy by elevation interaction

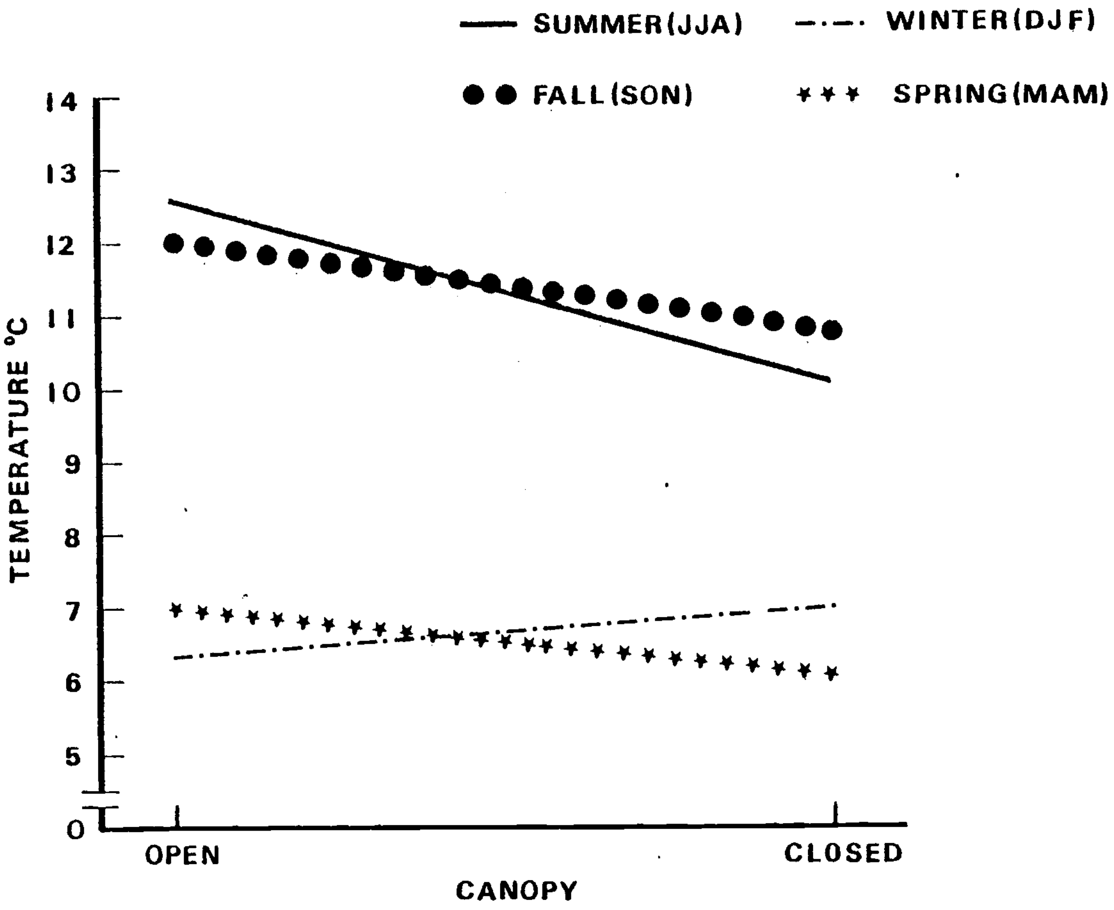

Figure 12. Canopy by season interaction

significant with or without 610 meters (Tables 3 and 5). Figure 15 illustrates this interaction. Even without 610 meters, the magnitude of differences between open and closed canopy decreases as elevation increases. This is probably due to canopy insulation, which is relatively more effective at lower elevations where there is a wider range of temperature to begin with. When comparing the 305 meter and 610 meter readings, there is a greater magnitude of difference between open and closed sites at 610 meters, again, probably due to the extremely warm temperatures at the 610 meter southerly open site.

Lack of parallelism among the curves in Figure 16 demonstrates an interaction between elevation and season even without the data from 610 meters. At 305 meters the summer season is the warmest, fall is only slightly cooler. Spring and winter are considerably colder, and winter is the coolest season. The same trend occurs at 610 meters, but between 610 and 762 meters the trends change. Fall becomes warmer than summer, and winter becomes warmer than spring. This same pattern occurs at all higher elevations. These data suggest that at higher elevations there is a lag time required for warming and cooling.

Effects of Season

The seasonal effect is obviously cyclic (Figure 17), and there are significant differences in average soil temperatures with or without 610 meter data (Tables 3 and 5). The warming cycle starts during the spring and proceeds to its maximum during late summer. The cooling cycle starts during late summer and lasts until its minimum

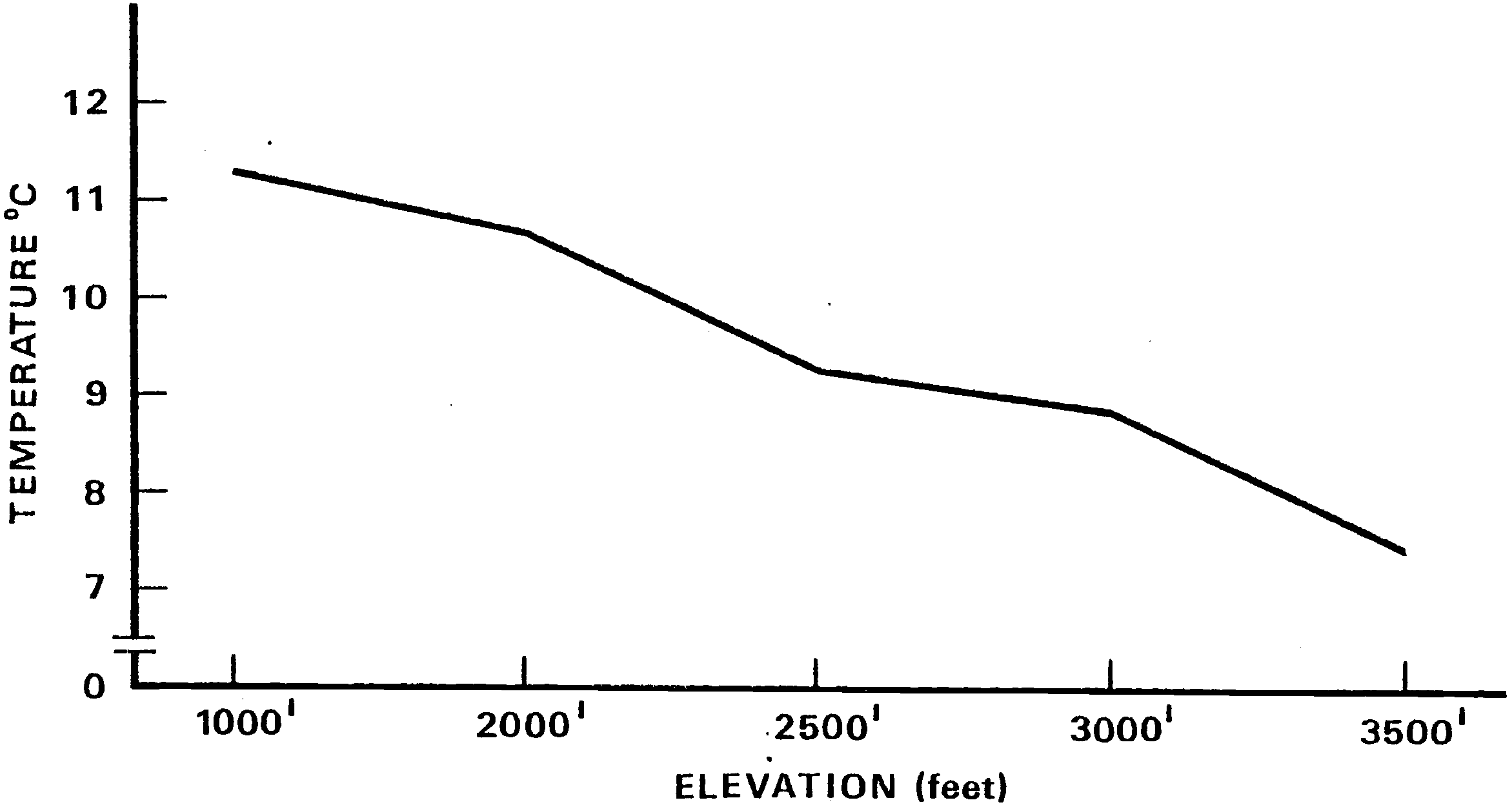

Figure 13. Main effect of elevation

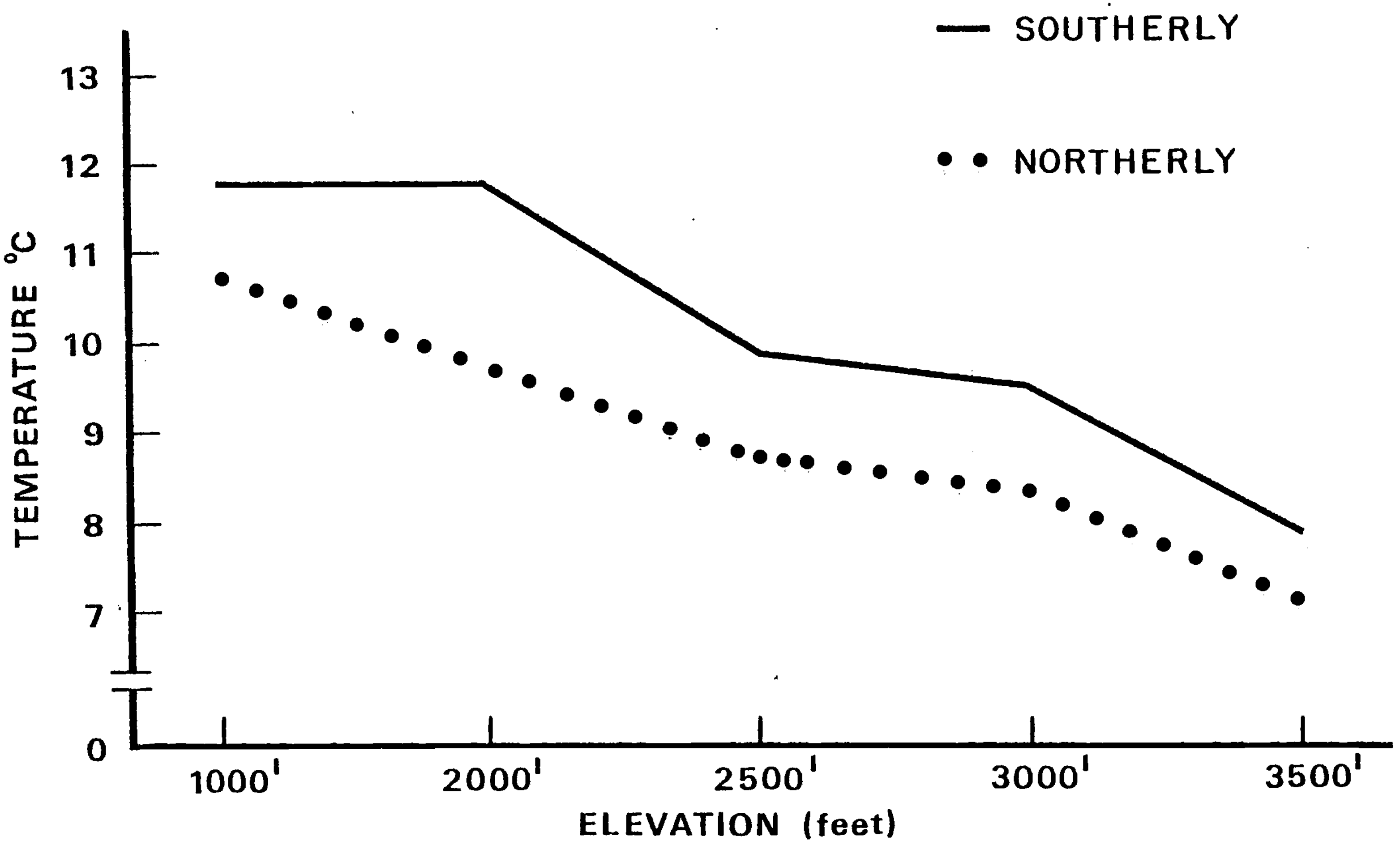

Figure 14. Elevation by aspect interaction

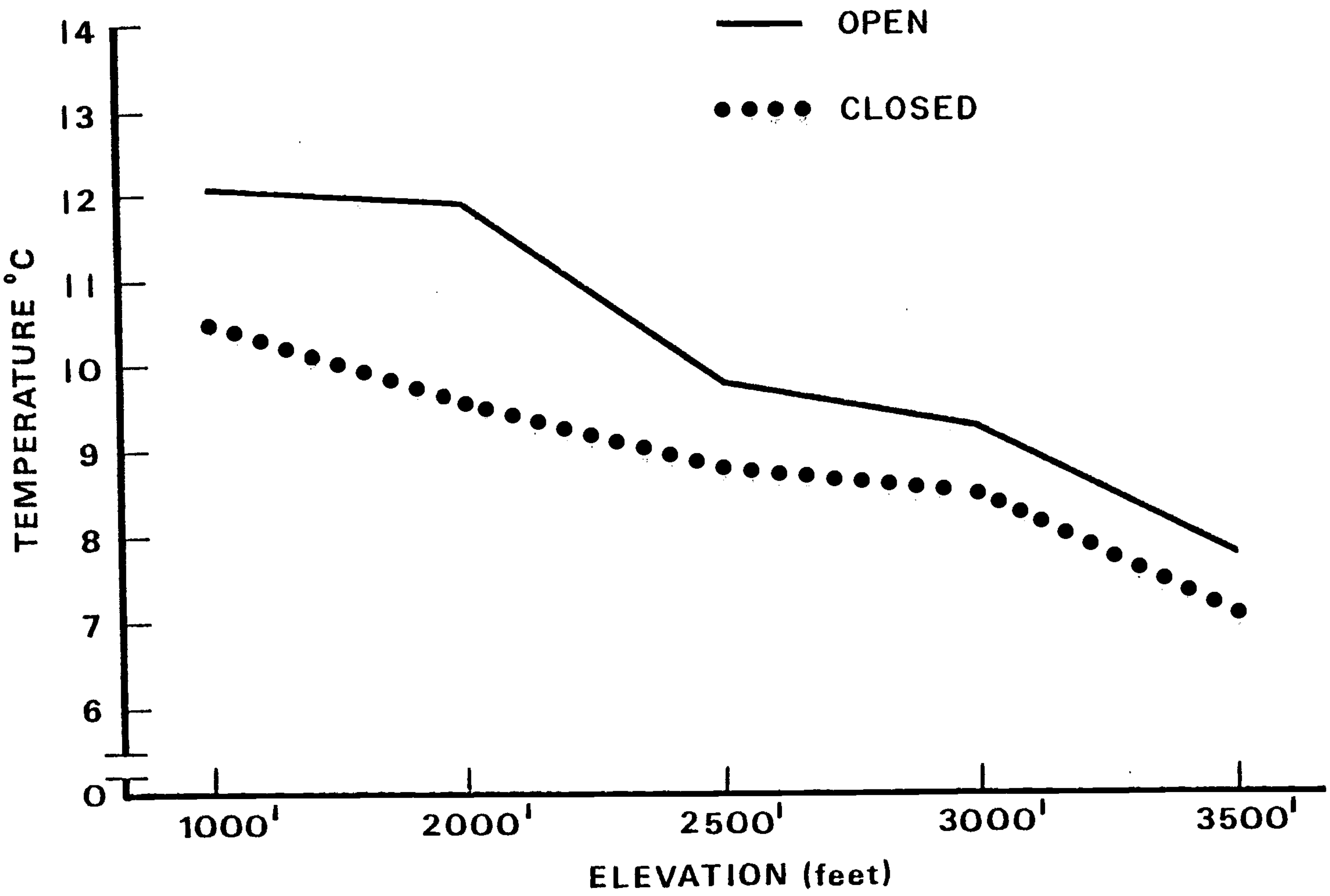

Figure 15. Elevation by canopy interaction

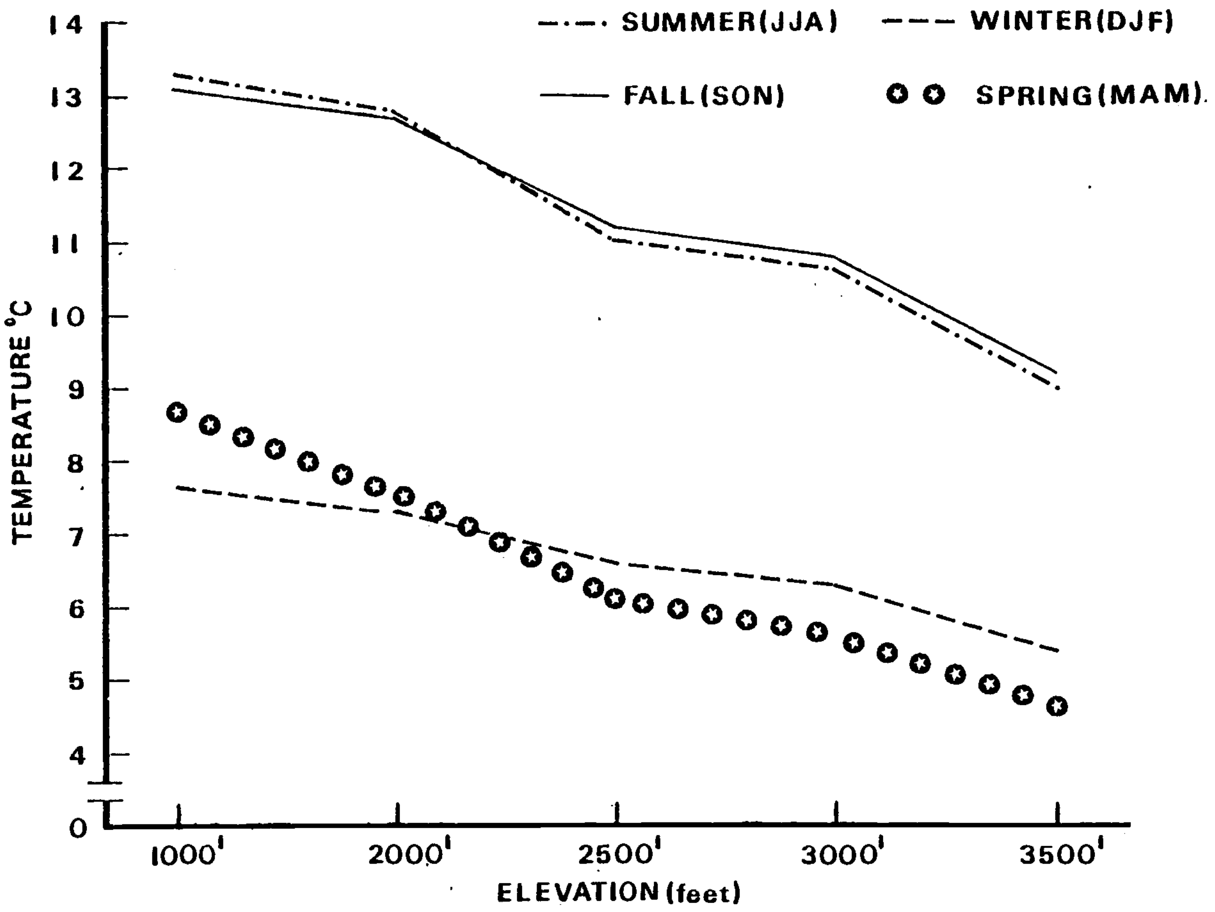

Figure 16. Elevation by season interaction

during late winter. The cyclic effect has been documented by numerous investigators (Soil Survey Staff, 1975; Schmidlin, 1981; Munn et al., 1978; Franzmeir et al., 1969; Toogood, 1979; Ouellet, 1973a; Ouellet and Desjardins, 1975). Franzmeir et al. (1969) attributed the cyclic effect to the change in potential direct radiation from summer to winter.

Graphical representation (Figure 18) of the interaction between season and aspect shows approximately parallel curves, suggesting no interaction. Statistically, however, this interaction is significant at the .05 level with or without the 610 meter level (Tables 3 and 5). Close examination of Figure 18 does indicate that the magnitude of temperature differences between northerly and southerly aspects does change slightly throughout the year. Summer and winter differences are the largest, and the transition periods of fall and spring are the least. The inconsistency of the magnitude of change is the cause for this interaction being significant, but the change is small and may not be important from a practical stand point.

Season by canopy interaction is definitely significant with or without 610 meter data (Figure 19: Tables 3 and 5). Open canopy sites are warmer during the spring, summer and early fall, whereas closed canopy sites are warmer during the winter. Apparently the full canopy acts as an insulator which moderates the temperatures throughout the year. During the spring, summer, and fall, the canopy reduces direct solar heating of the soil, and it remains cooler. During the winter, the canopy reduces heat loss from the surface, so the soil stays warmer.

The season by elevation interaction (Figure 20) is significant (Tables 3 and 5) even though the curves are roughly parallel. This is true with or without the 610 meter data. The magnitude of temperature differences between elevations is much greater during the summer than during the winter. Average temperatures at 305 and 610 meters are very similar throughout the year. Average temperatures at 762 and 914 meters also are similar to each other throughout the year, but the 1067 meter site is always cooler. Figure 16 also shows that the trend for summer to be the warmest season, followed by fall, spring, and winter, is true only at the lower elevations. At the higher elevations the trend is for fall to be the warmest season, followed by summer, winter and finally spring. This illustrates a lag time of warming and cooling occurring at elevations above 610 meters.

Figure 21 illustrates a three way interaction between aspect, canopy, and season. Temperatures under both closed canopies are very much the same throughout the year, but there is a great mangitude of difference between the two open sites. This difference is greatest during the summer and winter and the least during the fall and spring. It is also apparent that the difference between extreme temperatures is greater beneath the open sites than the closed sites. For example, the difference between extremes on northerly open is 9.9°C but on northerly closed it is only 8.5°C, and on southerly open 10.6°C but on southerly closed it is only 8.9°C.

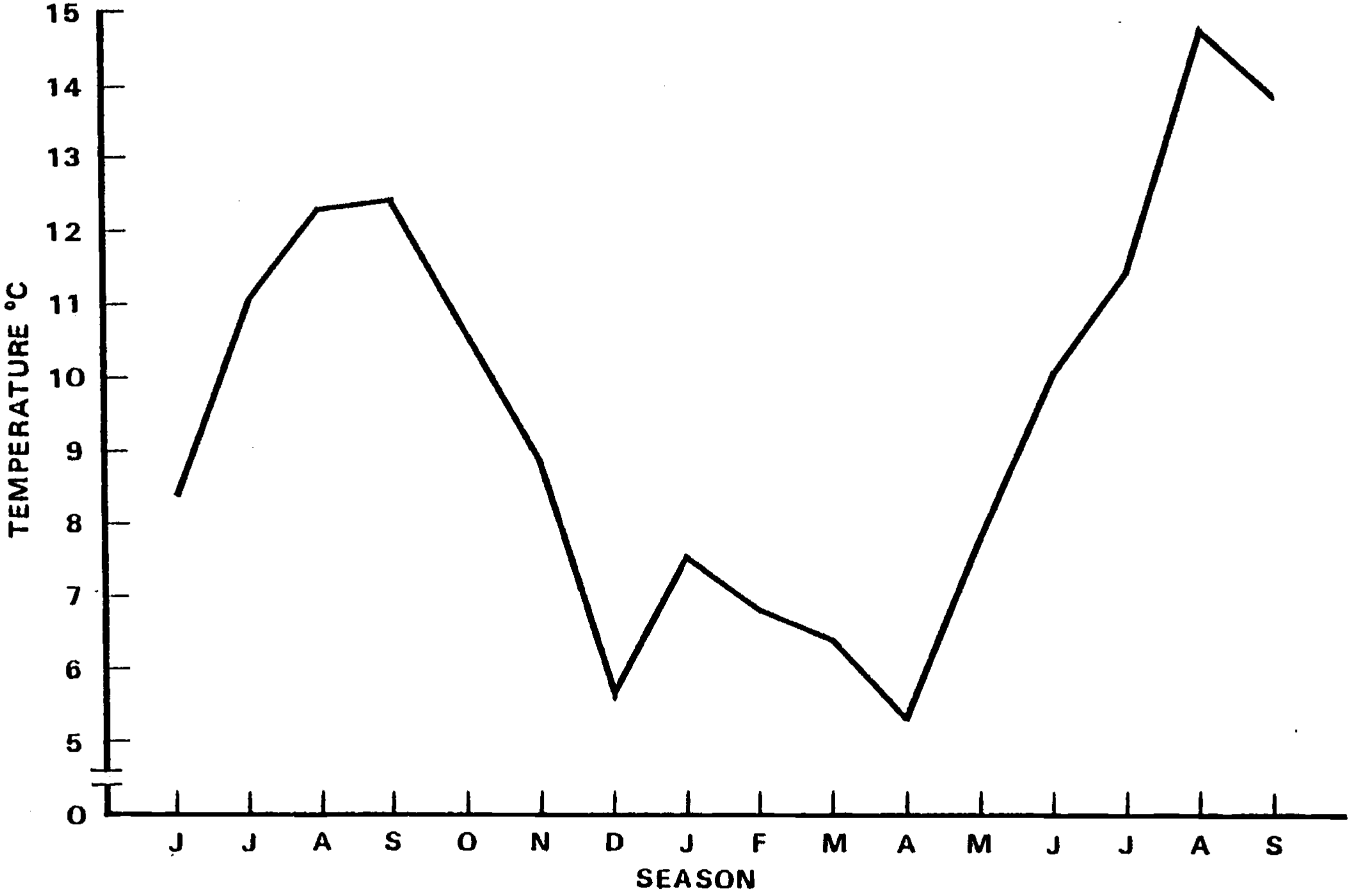

Figure 17. Main effect of season

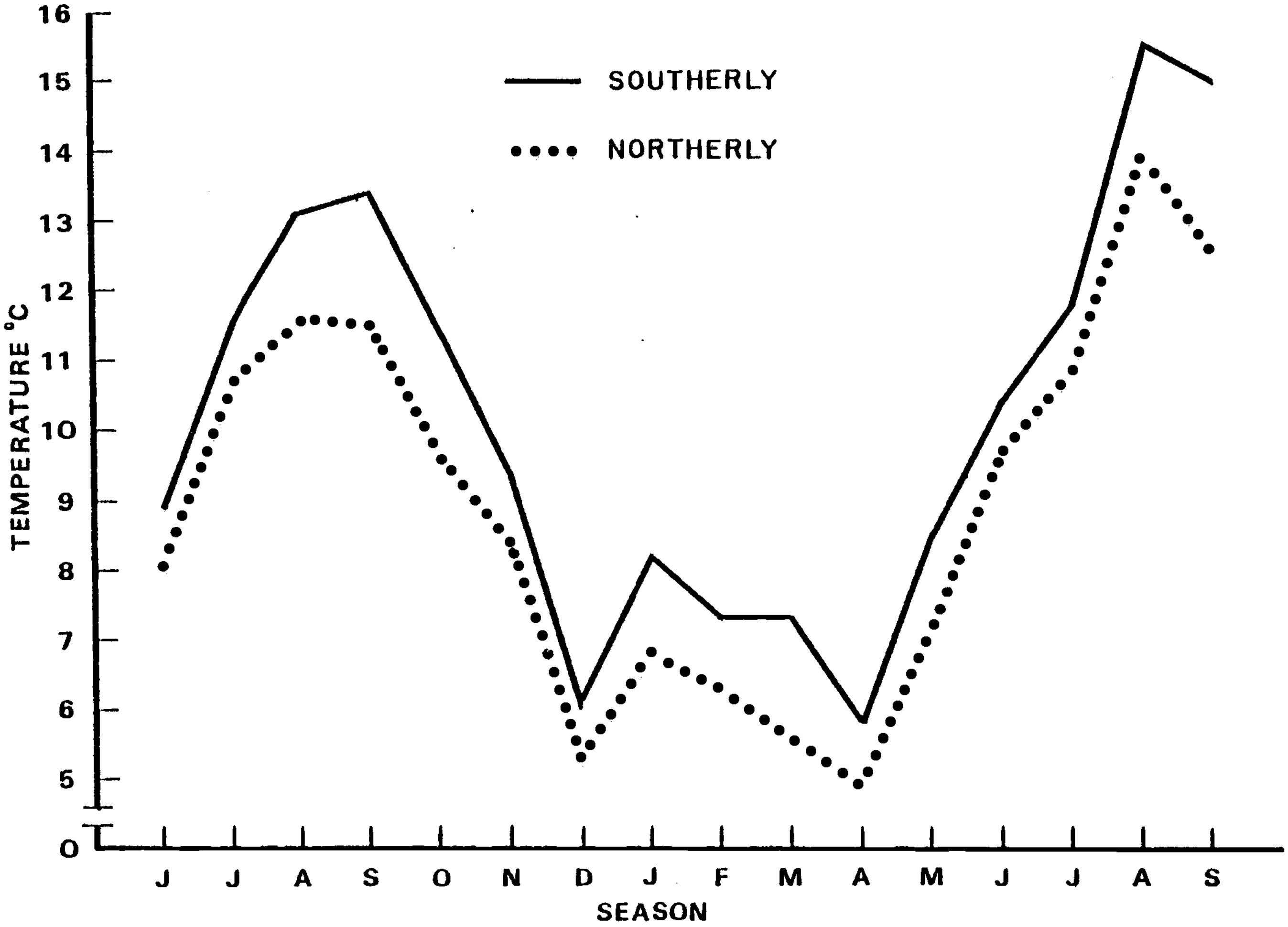

Figure 18. Season by aspect interaction

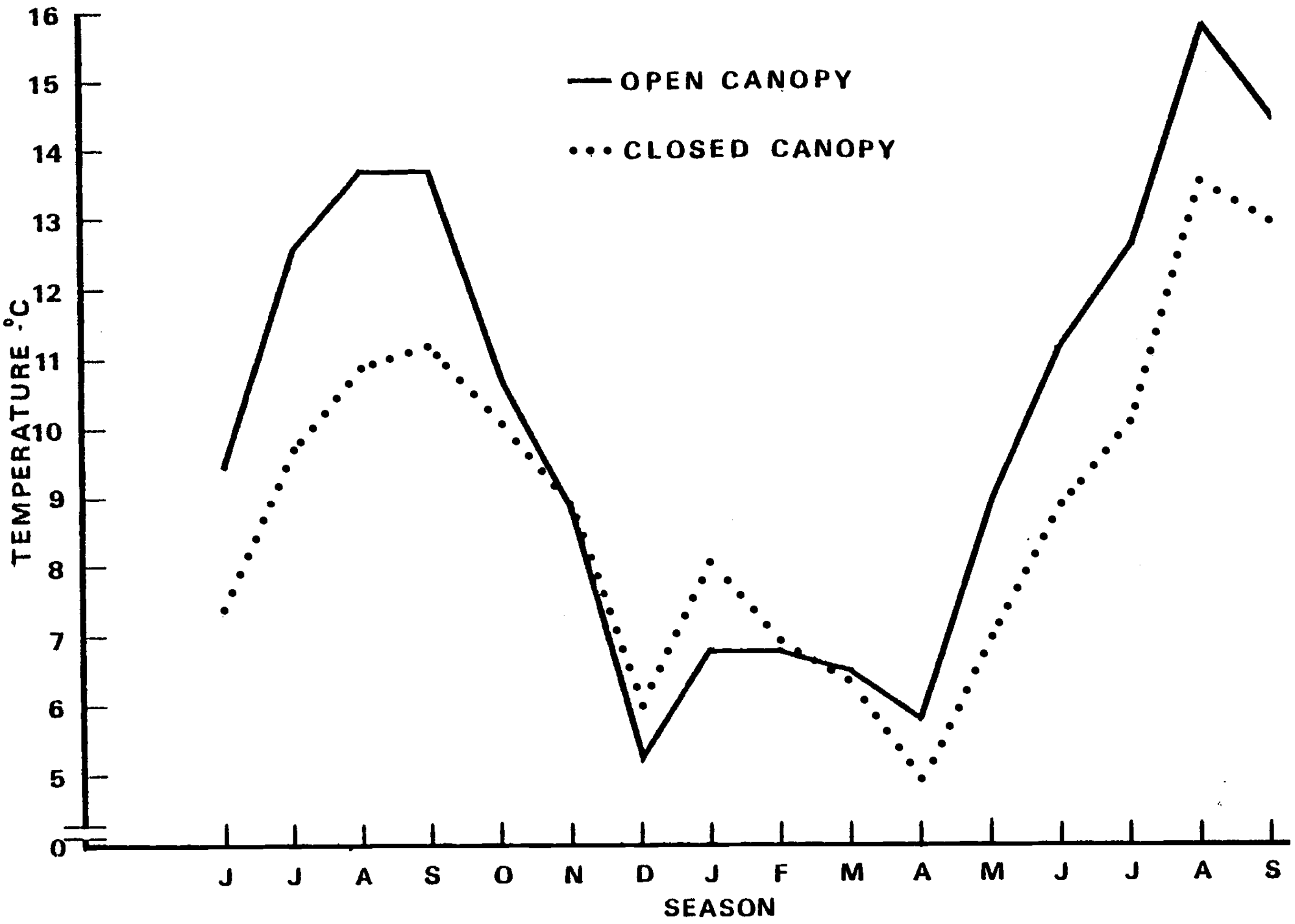

Figure 19. Season by canopy interaction

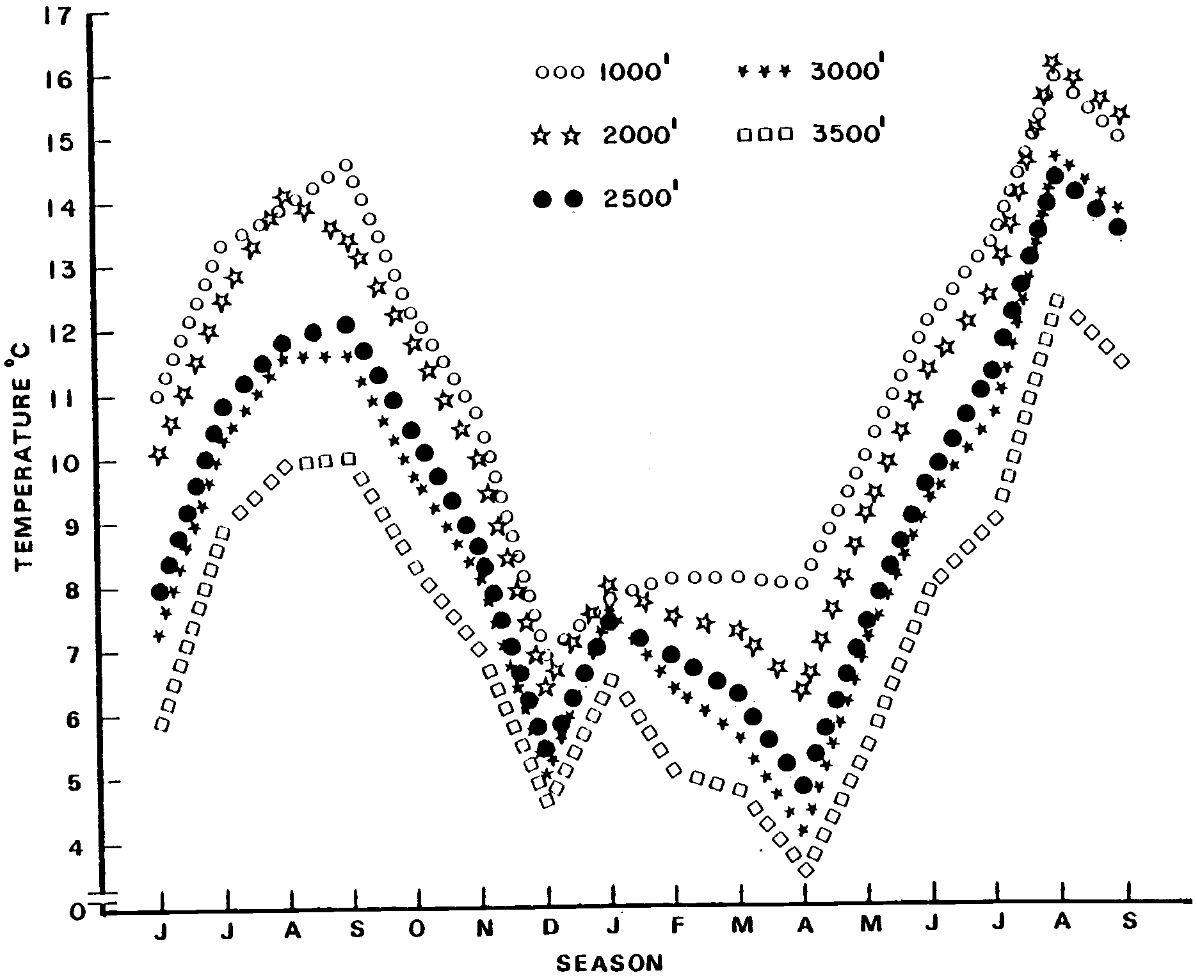

Figure 20. Season by elevation interaction

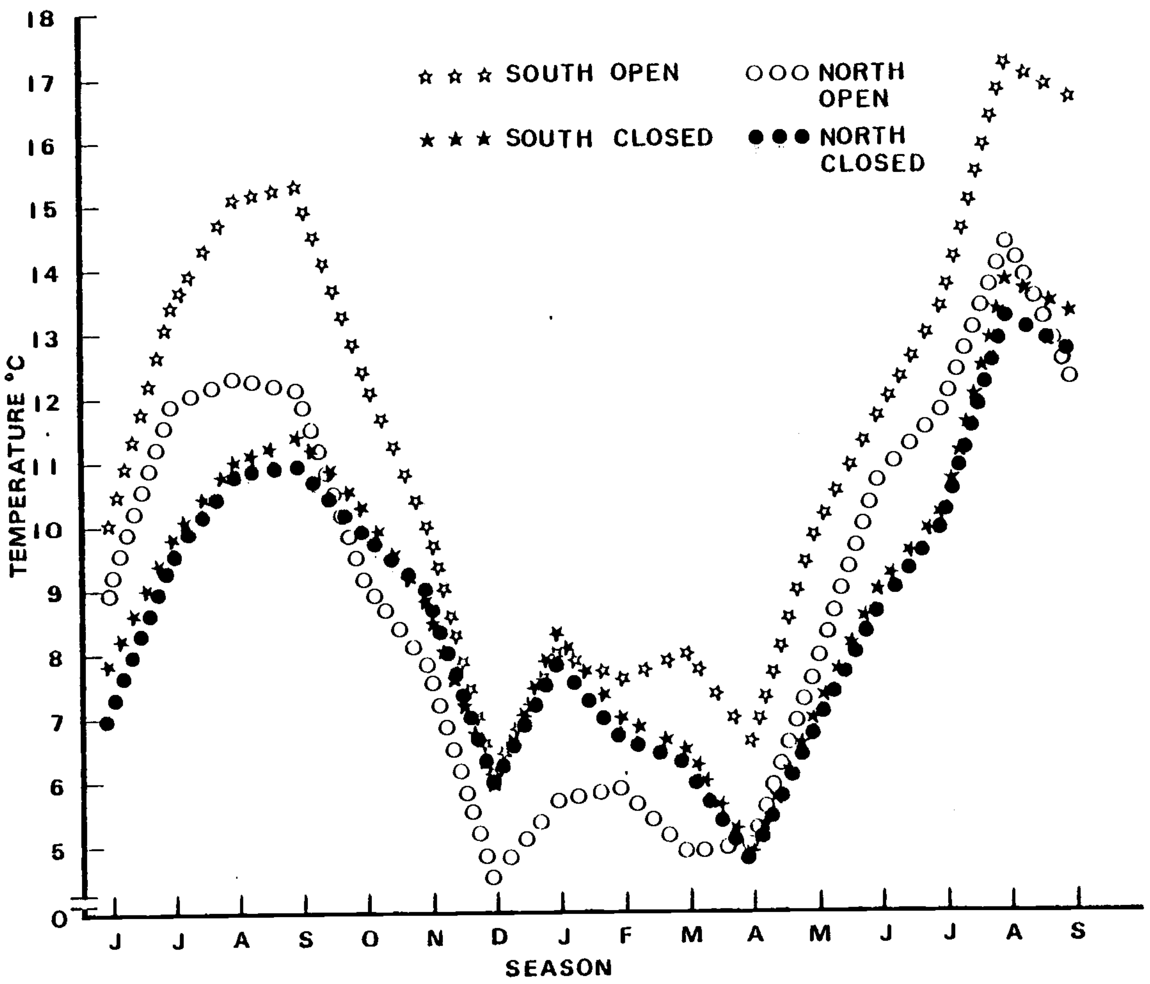

Figure 21. Aspect by canopy by season interaction

V. IMPLICATIONS FOR SOIL CLASSIFICATION

The data from this study have several important ramifications for soil classification. One concerns the criteria by which sites are selected for soil temperature measurement. Another concerns the possibility that iso-temperature regimes are more prevalent than is widely thought. A third concerns the appropriateness of the months currently used by the Soil Survey Staff (1975) to define summer and winter seasons. A fourth involves the possibility of predicting soil temperatures from a knowledge of site variables.

When soil classification is the primary reason for measuring soil temperatures, the following guidelines should be used in selecting sites. First, sites should be located on soils which represent the majority of soils occurring at the chosen elevation, aspect, and canopy cover. This would eliminate problems such as those created by the 610 meter southerly open site. The temperatures were warmer than at any other site, and the shallow skeletal soils were unlike the majority of deep silt loams occurring at this level. Second, if classification is to represent forested lands, then sites should have closed canopies. Classification of forested lands should represent natural conditions; therefore, areas altered by management practices such as clear cutting should be avoided when establishing temperature sites for forest soil classification purposes. However, if temperature data are needed to answer questions concerning management practices, then sites should be located in areas altered by management. Third, if regional, general temperature regimes are the goal, then sites on level ground, or ridgetops would be preferred so as to eliminate the effect of aspect. However, if the objective is to properly classify all the soils in an area, then sites might have to be placed on both aspects, since the elevation at which mesic-frigid or frigid-cryic changes occur will be dependent on aspect. Note, however, that aspect had little effect under closed canopy, however, data were from only 16 months, hardly enough to be conclusive.

Table 7 illustrates both the occurrence of iso-temperature regimes and the importance of the correct choice of months to represent summer and winter seasons. The Soil Survey Staff (1975) defined an iso-regime as one for which the mean summer and mean winter temperatures differ by less than 5°C. Summer months are defined as June, July and August, and winter months as December, January, and February. Table 7, column 1, shows that all closed canopy sites, plus the open sites at 1067 meters, differ by less than 5°C, and therefore, may be classified as iso. Of course, these data represent only one year, and long term records would be necessary before reaching a definite conclusion. The data simply suggest that this could be the case, and imply the need to acquire continuous records over time in order to resolve this question.

The months used by the Soil Survey Staff (1975) to calculate mean summer and mean winter temperatures were chosen to represent the coldest and warmest seasons of the year. Close examination of the data, however, indicate that these months may not represent the coldest and warmest seasons in the Oregon Coast Range. Table 7 shows two alternative choices for defining summer and winter seasons.

Table 7. Difference Between Mean Summer and Mean Winter Temperatures.

	Taxonomy	Alternative 1	Alternative 2
305 M. Southerly Open	7.7	8.3	7.7
305 M. Southerly Closed	4.5*	5.1	5.4
305 M. Northerly Open	6.9	7.4	7.1
305 M. Northerly Closed	3.6*	4.5*	4.8*
610 M. Southerly Open	7.6	8.6	9.0
610 M. Southerly Closed	3.1*	3.9*	4.9*
610 M. Northerly Open	7.4	8.1	8.1
610 M. Northerly Closed	3.8*	4.9*	5.9
762 M. Southerly Open	5.2	6.5	7.3
762 M. Southerly Closed	3.3*	4.3*	5.4
762 M. Northerly Open	6.3	6.9	7.4
762 M. Northerly Closed	2.8*	4.1*	5.2
914 M. Southerly Open	5.9	7.3	8.3
914 M. Southerly Closed	2.6*	4.5*	6.4
914 M. Northerly Open	5.9	6.6	7.1
914 M. Northerly Closed	2.7*	4.0*	5.5
1067 M. Southerly Open	4.7*	5.9	6.7
1067 M. Southerly Closed	2.4*	3.9*	5.2
1067 M. Northerly Open	4.9*	5.8	6.3
1067 M. Northerly Closed	2.3*	3.7*	5.1

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*Sites that would qualify as iso based only on this 16-month data record.

Alternative 1 uses July, August and September for the summer and January, February, and March for the winter. Alternative 2 uses July, August, and September for the summer and February, March, and April for the winter. Alternative 1 was based on the observation in the data that maximum summer and minimum winter temperatures lag behind the periods as defined in Taxonomy. So the next three consecutive months were used to see what would happen. Alternative 2 seasons were designed to represent the three consecutive coldest and warmest months, respectively, at the majority of sites. The three warmest consecutive months at all elevations are July, August and September (Table 8). The three coldest consecutive months are December, January and February at the lowest elevation and February, March and April at all higher elevations (Table 8).

Use of alternative 1 makes little difference in the classification. Only the site at 305 meter southerly closed and the two open sites at 1067 meters drop out of the iso-classification. However, the difference between mean summer and winter temperatures is much larger at all sites than for the Soil Survey Staff's months. This would be expected because the summer and winter seasons were warmer and colder, respectively, than the summer and winter seasons as defined by the Soil Survey Staff(1975). Alternative 2 maximizes the difference between mean coldest and mean warmest seasonal temperatures, and in this scheme only two sites are iso, and even these are very close to the 5°C limit. Therefore, if mean summer and winter temperatures are to represent the warmest and coldest periods, the months currently used to calculate these means may not be the right

Table 8. Average Temperature °C of All Sites at Each Elevation for Each Month

	305 m	610 m	762 m	914 m	1067 m
June	11.0	10.1	7.9	7.3	5.9
July	13.3	12.5	10.8	10.3	8.9
August	13.9	14.1	11.9	11.8	9.9
September	14.3	13.6	12.1	11.8	10.0
October	12.3	11.8	10.4	9.7	8.3
November	10.6	10.0	8.8	8.1	7.0
December	6.9	6.4	8.4	5.0	4.6
January	7.8	8.0	7.5	7.7	6.5
February	8.1	7.5	6.9	6.4	5.1
March	8.1	7.3	6.3	5.6	4.8
April	8.0	6.3	4.8	4.1	3.5
May	10.0	9.1	7.4	7.1	5.5
June	12.1	11.2	9.6	9.3	7.9
July	13.3	12.5	11.3	10.6	9.0
August	15.9	16.1	14.4	14.6	12.4
September	14.9	15.3	13.5	13.8	11.4

ones to use at the latitude of this study area. Serious consideration should be given to changing the definition, at least for some geographic areas, so that the resulting classification better represents the warmest and coolest periods.

Mathematical models for predicting mean annual soil temperatures have been developed from monthly soil temperature data (Munn et al., 1978; Carter and Ciolkosz, 1980; Soil Survey Staff, 1975; Smith et al., 1964; Rieger, 1973) and from site factors such as elevation, latitutde and longitude (Arkley, 1972; Munn and Nielsen, 1979; Schmidlin, 1981). By utilizing data collected on elevation, aspect, canopy, season, and their two-way interactions a model was developed for the Mary's Peak area (Table 9).

Seasons were defined according to Soil Survey Staff's (1975) criteria for summer and winter seasons. Season one represents December, January, and February; season two represents March, April, and May; season three represents June, July, and August; and season four represents September, October, and November. Data from 610 meters were left out of the regression analysis.

The backward elimination procedure (Neter and Wasserman, 1974) with a .05 level of confidence was used in determining which variables were left in the model and which ones were left out. The elevation by aspect interaction was the only variable dropped with this procedure, but the aspect by season interaction was small enough (p-value of .047) that it too was dropped with no significant drop in the R^2 value. If all or any of the other interactions were dropped the R^2 value dropped significantly. Therefore, by utilizing the raw data

Table 9. Temperature Prediction Model

Y = 11.9

-.0015 elevation
+ 1.93 aspect
- .59 canopy
- 4.41 Season 1
- 1.79 Season 2
+ 3.52 Season 3
+.0003 Elev. x Canopy
+.0006 Elev. x Season 1
-.0003 Elev. x Season 2
-.0002 Elev. x Season 3
- 1.74 Aspect x Canopy
+ 1.55 Canopy x Season 1
-.0078 Canopy x Season 2
- 1.37 Canopy x Season 3

R^2 = .98

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collected on elevation, aspect, canopy, season and the statistical interactions of elevation by canopy, elevation by season, aspect by canopy, and canopy by season, a regression model was developed for the Marys Peak area (Table 9), with an R^2 value of .98.

For use of the model the following definitions were made. Northerly aspects were defined as equaling 0, southerly aspects as equaling 1, open canopy as 0, and closed canopy as 1. If the equation is used to predict season 1, then season 1 would equal 1 and seasons 2 and 3 would equal 0; if season 2 is to be predicted, it would equal 1 and seasons 1 and 3 would equal 0; if season 3 is to be predicted, it would equal 1 and seasons 1 and 2 would equal 0. If season 4 is to be predicted, however, seasons 1, 2, and 3 would all equal -1. Elevation simply means the elevation for which the temperature is to be predicted.

This equation will make possible the prediction of soil temperatures based on the above site factors for soils of the Marys Peak area. The model, however, was developed with only 16 months of data, and long term records would be necessary before reaching a definite conclusion that this is the best model. The applicability of the model to other geographic areas would be suspect also until some minimum amount of calibrations were done by obtaining soil temperatures to validate or modify the equation.

VI. SUMMARY AND CONCLUSIONS

The effects which aspect, canopy, elevation, and season, both singly and in combination, have on soil temperatures at 50 cm depths were evaluated.

The objectives of the study were (i) to develop a standard procedure for obtaining soil temperature data adequate to classify soils at the family and great group levels, (ii) to evaluate the effects which aspect, canopy, elevation, and season singly and in combination have on soil temperatures, (iii) to evaluate the durability and consistency of selected instruments, and (iv) to test whether the months used by the Soil Survey Staff (1975) for calculating mean summer and winter temperatures are appropriate for this locality.

The basic procedure was to establish monitoring sites at enough different elevations to span the range of soil temperatures regimes from mesic to cryic. At each elevation, sites were located on both northerly and southerly aspects, and within each aspect under full forest canopy and in an opening or clearcut. Temperatures were read monthly using four different instruments. Mary's Peak, in the Oregon Coast Range was chosen as the general location for the study.

A number of methods were used in analysis of the data. Graphs showing various temperature interactions among the main site factors were started early in the study and updated every two months. The SIPS statistical package (Rowe and Brenne, 1981) was used to develop analysis of variance tables for seasons as defined by soil Taxonomy as well as for alternative seasons, which were based on the observation in the data that maximum summer and minimum winter temperatures lag behind the periods as defined in Taxonomy. Analysis of variance tables were constructed for these seasons both with and without data from 610 meters, to evaluate the effect of an unusually warm site at this level. The SIPS statistical package (Rowe and Brenne, 1981) was also used to develop a regression model utilizing Soil Taxonomy seasons without data from 610 meters.

The major results and recommendations found as a result of this study are:

A. All main effects of aspect, canopy, elevation, and season, when averaged over all other effects, were found to be significant, graphically as well as statistically. This was true both in the analysis of data according to the seasons defined by soil taxonomy and in the analysis using seasons offset by one month. It was also true whether or not the data from 610 meters, which contained an unusually warm site, were included.

B. Using seasons as defined by Soil Survey Staff (1975) and including data from 610 meters, all six two-way interactions, elevation by aspect, elevation by canopy, aspect by canopy, elevation by season, aspect by season, and canopy by season were found to be significant at the .05 level of significance.

C. Using Soil Survey Staff's seasons but excluding data from 610 meters, elevation by canopy, aspect by canopy, elevation by season, canopy by season, and aspect by season were statistically significant.

D. Using alternate seasons of July, August, and September for summer and January, February, and March for winter and including data from 610 meters, all interactions except aspect by season were significant both graphically and statistically.

E. Using alternate seasons and excluding data from 610 meters all interactions were significant graphically as well as statistically except for the aspect by elevation interaction.

Probably the primary reason for the above interactions being significant is due to the insulating effect of canopy, compounded with direct exposure on southerly aspects, that modifies or moderates the direct elevation effect.

F. There was evidence of possible iso-temperature regimes occurring under closed canopy conditions at all elevations on both aspects if seasons were defined according to Soil Survey Staff (1975) guidelines. However, if seasons are defined to truly represent the three consecutive coldest and warmest months, then only two sites at 305 meters northerly closed and 610 meters southerly closed remained iso.

G. A regression model with an R^2 value of .98 was developed for the Marys Peak area. Variables included aspect, canopy, elevation, season, and two-way interactions; elevation by canopy, elevation by season, aspect by canopy, and canopy by season.

H. There were no significant differences between selected instruments concerning consistency. However, data from the YSI Thermistor probes were used for the analysis work.

Recommendations based on results of this study include:

1. Temperature sites should be located under closed canopy conditions if soil temperatures are to be used for classification of forest soils.

2. Temperature sites should be located on soils which are representative of the majority of soils occurring under selected site conditions to avoid problems such as those resulting from data at 610 meters southerly open.

3. The months July, August, and September better represent the three consecutive warmest months and therefore, best represent the mean summer soil temperature.

4. The months February, March, and April better represent the three consecutive coldest months, and therefore, best represent the mean winter soil temperatures.

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APPENDICES

APPENDIX I

Temperature data for all sites from June, 1980 to September, 1981. Data are in °F. for Soiltest thermometers and °C. for Weston thermometers and thermistor beads and probes.

MARYS PEAK SOIL TEMPERATURE DATA

Location: SE¼Sec1T12SR7W Elevation: 305 Meters

Aspect: Southerly % Cover: Open

Slope: 25%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	54.5	54.5	14	13.5	12.5	12.5
July 1980	60	60	16	16	15.5	15.5
August 1980	60	60	17	18	17	17
September 1980	63	63	17	18	17	17
October 1980	57	57	14.5	14.5	14	14
November 1980	54	54	12	12.5	11.5	12
December 1980	45	45	7.5	7.5	7	7
January 1981	46	46	7.5	8	8	8
February 1981	47	47	8	8.5	8.5	8.5
March 1981	49	49	9.5	9.5	9.5	9.5
April 1981	50	50	10	10	9.5	10
May 1981	53	54	12	12	12	12
June 1981	57	57	13.5	13.5	13.5	13.5
July 1981	60	60	16	15.5	15.5	15.5
August 1981	66	66	19	19	19	19
September 1981	65	65	18.5	18.5	18	18

MARYS PEAK SOIL TEMPERATURE DATA

Location: SE¼Sec1T12SR7W

Elevation: 305 Meters

Aspect: Southerly

% Cover: Closed

Slope: 28%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	50	50	11	11	9.5	9.5
July 1980	54	52	12.5	12.5	12	12
August 1980	54	54	13.5	13.5	12.5	12.5
September 1980	54	54	13	13.5	12.5	12.5
October 1980	54	55	12	12.5	12	12
November 1980	52	52	11	11	10.5	10.5
December 1980	44	45	7	7.5	6.5	7
January 1981	46	46	8	8	8	8
February 1981	46	46	8	8	8	8
March 1981	46	46	7.5	7.5	8	8
April 1981	46	45	7.5	7.5	7	7
May 1981	49	49	9	9.5	9	9
June 1981	52	52	11	11	11.5	11.5
July 1981	55	55	12.5	12.5	12.5	12.5
August 1981	59	59	15	15	15	15
September 1981	58	58	15	14.5	14	14

MARYS PEAK SOIL TEMPERATURE DATA

Location: NW¼Sec1T12SR7W

Elevation: 305 Meters

Aspect: Northerly

% Cover: Open

Slope: 10%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	55	55	13	13	12.5	12.5
July 1980	56	56	15	15	14.5	14
August 1980	56	56	16	16	14	14
September 1980	63	63	17	17	16.5	16.5
October 1980	53	54	12	12.5	11	11.5
November 1980	50	50	10	10.5	9.5	9.5
December 1980	42	43	6	6	5.5	6
January 1981	44	44	6	6	6	6.5
February 1981	45	45	7.5	7	7	7.5
March 1981	44	44	6.5	6.5	6.5	7
April 1981	46	46	8	7.5	7.5	7.5
May 1981	50	50	10	10	10	10
June 1981	53	54	12.5	12.5	12.5	12.5
July 1981	56	55	13	13	13.5	13.5
August 1981	59	59	15	15	15	15
September 1981	56	56	13	13	13	13.5

MARYS PEAK SOIL TEMPERATURE DATA

Location: NW¼Sec1T12SR7W

Elevation: 305 Meters

Aspect: Northerly

% Cover: Closed

Slope: 34%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	49	49	10	10	9.5	9.5
July 1980	52	52	12	12.5	11.5	11.5
August 1980	54	54	13.5	13.5	12.5	12
September 1980	54	54	13	13	12.5	12.5
October 1980	54	54	12	12	11.5	11.5
November 1980	51	52	11.5	11.5	10.5	10.5
December 1980	45	45	7	7	7	7.5
January 1981	46	47	8	8	8	8.5
February 1981	46	47	8	8.5	8.5	8.5
March 1981	46	46	8.5	8	8	8
April 1981	46	46	7.5	7.5	7.5	7.5
May 1981	49	49	9.5	10	9	9
June 1981	52	52	11	11	11	11
July 1981	55	54	12	12.5	12	12
August 1981	59	59	14.5	15	15	14.5
September 1981	58	58	13.5	13.5	14	14

MARYS PEAK SOIL TEMPERATURE DATA

Location: NW¼Sec2T13SR7W

Elevation: 457 Meters

Aspect: Southerly

% Cover: Closed

Slope: 22%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	47	47	10	9	8.5	8.5
July 1980	50	51	11.5	11.5	11	10.5
August 1980	53	53	13.5	13.5	12	12
September 1980	52	53	12	12	12.5	12.5
October 1980	54	54	13	13.5	11	11.5
November 1980	50	50	10	10.5	9.5	9
December 1980	44	44	6	6	6	6
January 1981	46	46	7.5	7.5	7.5	7.5
February 1981	45	45	7.5	7.5	7.5	7.5
March 1981	45	46	7.5	8	7.5	7.5
April 1981	43	43	6	6.5	6	6.5
May 1981	47	47	8.5	8.5	8.5	8.5
June 1981	50	50	10	10	10	10
July 1981	53	53	11.5	11.5	11.5	11.5
August 1981	57	58	14.5	14.5	14.5	14.5
September 1981	57	57	14.5	14.5	14	14

MARYS PEAK SOIL TEMPERATURE DATA

Location: NW¼Sec2T13SR7W   Elevation: 457 Meters

Aspect: Northerly   % Cover: Closed

Slope: 55%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	47	47	9	9.5	8.5	9
July 1980	52	52	12	13	11	11
August 1980	53	54	13.5	13.5	12.5	12.5
September 1980	53	54	13	13	12.5	12.5
October 1980	53	54	12.5	13	11.5	11.5
November 1980	49	50	11	10	10.5	10.5
December 1980	44	44	6.5	6.5	6.5	7
January 1981	45	45	7.5	7.5	7.5	8
February 1981	45	45	7.5	7.5	7.5	7.5
March 1981	46	45	8	8	8	8
April 1981	44	44	6.5	6.5	6.5	6.5
May 1981	48	48	8.5	9	9	9
June 1981	50	50	10	10	10	10
July 1981	53	54	11.5	11.5	11.5	11.5
August 1981	58	59	14.5	14.5	14.5	14.5
September 1981	58	58	15	15	14.5	14.5

MARYS PEAK SOIL TEMPERATURE DATA

Location: NE¼Sec3T12SR7W
Elevation: 610 Meters
Aspect: Southerly
% Cover: Closed
Slope: 32%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	52	52	11	11	10.5	10.5
July 1980	49	50	11	11	10	9.5
August 1980	53	52	13	13.5	11.5	11.5
September 1980	53	54	12.5	12.5	12	12
October 1980	54	54	13	13	11	11.5
November 1980	48	49	10	10	9.5	10
December 1980	42	42	5.5	6	6.5	7
January 1981	48	48	9	9	9	9
February 1981	46	46	7.5	8	8	7.5
March 1981	46	46	7.5	7.5	7.5	7.5
April 1981	43	42	6.5	6	5.5	6
May 1981	47	47	8	8	8	8
June 1981	49	49	10	9.5	9.5	9.5
July 1981	52	52	11	11	11	10.5
August 1981	57	58	14.5	14	14.5	14
September 1981	57	57	15	15	14	14

MARYS PEAK SOIL TEMPERATURE DATA

Location: SW¼Sec35T12SR7W Elevation: 610 Meters

Aspect: Southerly % Cover: Open

Slope: 50%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	54	54	13	13	12.5	12.5
July 1980	61	61	17	17	16	16.5
August 1980	65	65	19	18.5	18	18.5
September 1980	64	64	19	19	18.5	18.5
October 1980	59	60	17.5	16.5	15	15
November 1980	52	53	12	12.5	12	12
December 1980	44	44	7	7	7.5	7
January 1981	49	49	10	10	9.5	9.5
February 1981	49	49	9.5	9.5	9.5	9.5
March 1981	50	50	10	10	10	10
April 1981	47	47	8.5	9	8.5	8.5
May 1981	54	55	12.5	12	12	12.5
June 1981	58	57	14	14	14	14
July 1981	62	62	16	16.5	16	16
August 1981	70	69	20.5	20	20.5	20.5
September 1981	69	69	20	20	20	20

MARYS PEAK SOIL TEMPERATURE DATA

Location: SW¼Sec15T12SR7W

Elevation: 610 Meters

Aspect: Northerly

% Cover: Open

Slope: 32%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	48	48	10.5	10.5	10	9.5
July 1980	55	55	14	14.5	13.5	13.5
August 1980	57	56	15	16	14	14.5
September 1980	53	54	12	12.5	12.5	12.5
October 1980	51	51	11.5	11.5	10	10
November 1980	47	47	9	9	8.5	8.5
December 1980	40	40	4	4	5.5	5.5
January 1981	41	42	5.5	5.5	5.5	5.5
February 1981	43	43	6	6	6	6
March 1981	41	41	5	5.5	5.5	5.5
April 1981	41	41	5.5	5.5	5.5	5.5
May 1981	48	48	9	9	8.5	8.5
June 1981	54	54	12	12	12.5	12.5
July 1981	56	56	13	13	13	13
August 1981	60	60	15.5	15.5	15.5	15.5
September 1981	56	56	13.5	13.5	13.5	13.5

MARYS PEAK SOIL TEMPERATURE DATA

Location: NW¼Sec22T12SR7W   Elevation: 610 Meters

Aspect: Northerly   % Cover: Closed

Slope: 12%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	45	45	9	9	7.5	8
July 1980	50	50	11	11	10.5	10.5
August 1980	52	52	12.5	12.5	12	12
September 1980	52	52	11.5	11.5	11.5	11.5
October 1980	52	52	11	11	10.5	10.5
November 1980	50	50	10	10	9.5	9.5
December 1980	42	43	5.5	6	6	6
January 1981	47	47	8	8.5	8	8
February 1981	44	45	7	7	7	7
March 1981	44	44	7	6.5	6.5	6.5
April 1981	42	41	5.5	5.5	5	5
May 1981	46	46	8	8	7	7.5
June 1981	49	49	9.5	9.5	9.5	9
July 1981	52	52	11	11	10.5	10.5
August 1981	57	57	14	14	14.5	14.5
September 1981	57	57	13.5	13.5	13.5	13.5

MARYS PEAK SOIL TEMPERATURE DATA

Location: SE¼Sec28T12SR7W Elevation: 762 Meters

Aspect: Southerly % Cover: Open

Slope: 37%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	47	47	9	9	9	9
July 1980	53	54	13	13	12	12
August 1980	54	55	12.5	13	14	14
September 1980	60	60	15.5	16	15	15
October 1980	55	55	13.5	14	12.5	12.5
November 1980	49	48	10	10	9.5	9.5
December 1980	42	42	6	6.5	6	6
January 1981	45	46	7.5	8	8	8
February 1981	45	45	7	7	7.5	7.5
March 1981	47	46	8.5	8.5	8	8
April 1981	43	43	6	6	5.5	5.5
May 1981	50	49	10	9.5	9	9
June 1981	52	52	11	11	11	11
July 1981	55	55	12.5	12.5	12.5	12.5
August 1981	61	61	16	16	16	16
September 1981	62	63	16	16	16.5	16.5

MARYS PEAK SOIL TEMPERATURE DATA

Location: SE¼Sec28T12SR7W
Elevation: 762 Meters
Aspect: Southerly
% Cover: Close
Slope: 35%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	43	43	8	8	7.5	7.5
July 1980	48	48	10.5	10.5	9.5	10
August 1980	50	50	10.5	10.5	11	11
September 1980	52	52	12	12	11.5	11.5
October 1980	53	52	12	12	10	10.5
November 1980	47	47	9	9	9	9
December 1980	42	42	5	5	5.5	5.5
January 1981	47	47	8.5	8	8	8.5
February 1981	44	44	7	7	7	7
March 1981	43	43	6.5	7	6.5	6.5
April 1981	40	40	5	5	4.5	5
May 1981	45	45	7	7.5	7	7
June 1981	48	48	9	9	9	9
July 1981	51	51	10.5	10.5	10.5	10.5
August 1981	57	57	13	13.5	13.5	13.5
September 1981	56	57	12.5	12.5	13	13

MARYS PEAK SOIL TEMPERATURE DATA

Location: SE¼Sec34T12SR7W
Elevation: 762 Meters
Aspect: Northerly
% Cover: Open
Slope: 63%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	44	44	8.5	8.5	8.5	8.5
July 1980	50	51	11.5	12	12.5	12
August 1980	52	52	11.5	11.5	12	12
September 1980	52	52	12	12	11.5	11.5
October 1980	49	49	10	10	8	8.5
November 1980	44	45	8	8	7	7.5
December 1980	40	40	5	5	3.5	4
January 1981	43	43	6	6	5	5.5
February 1981	43	43	6	6	6.5	6.5
March 1981	40	40	5.5	5	4	4.5
April 1981	40	39	4	4	3.5	4
May 1981	45	45	7.5	7.5	7.5	7
June 1981	49	49	9	9	10	10
July 1981	53	53	12	11.5	12.5	12
August 1981	59	59	15	15	15	15
September 1981	54	54	11.5	11.5	12	12

MARYS PEAK SOIL TEMPERATURE DATA

Location: NW¼Sec34T12SR7W Elevation: 762 Meters

Aspect: Northerly % Cover: Closed

Slope: 35%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors Bead °C	Thermistors Probe °C
June 1980	43	43	7.5	7	6.5	6.5
July 1980	48	48	10	10	9	9
August 1980	50	50	10.5	10	10.5	10.5
September 1980	50	52	12	11.5	10.5	10.5
October 1980	51	51	11.5	11.5	10	10
November 1980	47	48	9.5	10	9	9
December 1980	42	43	5.5	6	6	6
January 1981	46	46	7.5	8	8	8
February 1981	43	44	6	7	6.5	6.5
March 1981	42	43	6.5	6.5	6	6
April 1981	41	40	5	5	4.5	4.5
May 1981	44	44	7	6.5	6.5	6.5
June 1981	47	47	8.5	8.5	8.5	8.5
July 1981	50	50	10	10	10	10
August 1981	56	56	13	13	13	13
September 1981	55	56	12.5	12.5	12.5	12.5

MARYS PEAK SOIL TEMPERATURE DATA

Location: NE¼Sec29T12SR7W
Elevation: 914 Meters
Aspect: Southerly
% Cover: Open
Slope: 52%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	45	46	8.5	8.5	8.5	8.5
July 1980	53	53	12.5	13	12.5	12.5
August 1980	56	57	15	15	14.5	14.5
September 1980	56	56	14.5	14	14.5	14.5
October 1980	52	52	12.5	12.5	10.5	11
November 1980	46	47	8.5	9	8.5	8.5
December 1980	40	40	5	4.5	5	5
January 1981	46	46	8	8	8	8
February 1981	44	44	7	7	7	7
March 1981	44	44	7	7	7	7
April 1981	40	39	4.5	4	5	5
May 1981	48	48	8.5	9	9	9
June 1981	51	51	10.5	10.5	10.5	10.5
July 1981	55	55	12.5	12.5	12.5	12.5
August 1981	63	63	17	17	17	17
September 1981	60	61	16	16	16.5	16.5

MARYS PEAK SOIL TEMPERATURE DATA

Location:	NE¼Sec29T12SR7W	Elevation:	914 Meters
Aspect:	Southerly	% Cover:	Closed
Slope:	52%		

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors Bead °C	Thermistors Probe °C
June 1980	42	42	6.5	6.5	6.5	6.5
July 1980	46	47	10	10	9	9.5
August 1980	51	50	13	13	10.5	11
September 1980	50	50	11	11	11	11.5
October 1980	50	50	10	10	9.5	9.5
November 1980	44	44	8	8	8	7.5
December 1980	41	41	5	5	5.5	5.5
January 1981	47	48	8	8.5	8.5	9
February 1981	44	44	6.5	7	7	7
March 1981	43	43	5.5	5.5	6	6.5
April 1981	39	39	3.5	4	4	3.5
May 1981	43	43	6.5	6.5	6	6
June 1981	46	46	8	8	8	8
July 1981	50	49	9.5	9.5	9.5	9.5
August 1981	56	57	13	13	13.5	14.5
September 1981	57	57	13.5	13.5	13	14

MARYS PEAK SOIL TEMPERATURE DATA

Location: SE¼Sec34T12SR7W
Elevation: 914 Meters

Aspect: Northerly
% Cover: Open

Slope: 70%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	44	44	8	8	8	7.5
July 1980	48	49	11	10.5	10.5	10
August 1980	51	51	11	11	11.5	11
September 1980	49	49	11	11.5	10.5	10.5
October 1980	48	49	10	10	8.5	8.5
November 1980	45	45	8	8	7.5	7.5
December 1980	39	39	4	3.5	4	3.5
January 1981	43	43	6	6	5.5	5.5
February 1981	42	42	4.5	5	5	5
March 1981	40	40	4.5	4.5	4	4
April 1981	38	38	4	4	4	4
May 1981	43	43	6.5	7	6.5	7
June 1981	48	48	9.5	9	10	10
July 1981	52	53	11.5	11.5	11	11
August 1981	56	56	13	13	13.5	14
September 1981	54	54	12	12	11.5	12

MARYS PEAK SOIL TEMPERATURE DATA

Location: SW¼S34T12SR7W

Elevation: 914 Meters

Aspect: Northerly

% Cover: Closed

Slope: 40%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	42	42	7.5	7	6.5	6.5
July 1980	47	47	9.5	9.5	8.5	9
August 1980	50	51	11	11	10.5	10.5
September 1980	50	50	11	11	10.5	10.5
October 1980	51	50	10.5	11	9	9.5
November 1980	47	48	9	9	8.5	9
December 1980	42	42	5.5	6	6	6
January 1981	46	47	8	8	8	8
February 1981	44	44	6.5	6.5	6.5	6.5
March 1981	42	42	6	6	6.5	6
April 1981	38	38	4	4	4	4
May 1981	42	42	6	6	6	6.5
June 1981	46	46	8	8	8	8.5
July 1981	50	50	10	10	9.5	9.5
August 1981	56	56	13	13	13	13
September 1981	55	55	13	13	12.5	12.5

MARYS PEAK SOIL TEMPERATURE DATA

Location: SE¼Sec20T12SR7W

Elevation: 1067 Meters

Aspect: Southerly

% Cover: Open

Slope: 5%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	44	44	7.5	7.5	7.5	7.5
July 1980	48	50	11	11	10.5	10.5
August 1980	53	53	13	13	11.5	11.5
September 1980	52	52	11.5	11	12	11.5
October 1980	50	51	11.5	12	9	9.5
November 1980	44	44	8	8	7	8
December 1980	40	40	5	5	5	5.5
January 1981	43	43	6	6	6	6.5
February 1981	41	41	5	5	5.5	5.5
March 1981	42	42	5.5	5.5	5	5.5
April 1981	38	38	4	3.5	3	4
May 1981	45	45	7	7.5	7	7
June 1981	48	49	9	9	9.5	9.5
July 1981	51	51	10.5	10.5	11	10.5
August 1981	58	58	14	14	13	13.5
September 1981	55	55	12.5	12.5	12.5	12.5

MARYS PEAK SOIL TEMPERATURE DATA

Location: SE¼Sec20T12SR7W Elevation: 1067 Meters

Aspect: Southerly % Cover: Closed

Slope: 35%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	40	40	5.5	5.5	5	5
July 1980	44	45	8	8.5	8	8
August 1980	46	46	8.5	9	9.5	9
September 1980	47	47	9	9	9.5	9.5
October 1980	46	47	9	8.5	7.5	8
November 1980	43	43	7	7.5	6.5	7
December 1980	40	39	4.5	4	4.5	5
January 1981	45	45	7	7	7	7
February 1981	42	42	5.5	5.5	5.5	5.5
March 1981	40	40	5	4.5	4.5	5
April 1981	37	37	3	2.5	3	3
May 1981	40	40	5	5	4.5	5
June 1981	44	44	7	6.5	7	7
July 1981	47	47	8	8	8	8
August 1981	52	52	12	11	12.5	12
September 1981	52	53	10.5	10.5	11.5	11.5

MARYS PEAK SOIL TEMPERATURE DATA

Location: SW¼Sec20T12SR7W   Elevation: 1067 Meters

Aspect: Northerly   % Cover: Open

Slope: 45%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors Bead °C	Thermistors Probe °C
June 1980	42	42	6	6.5	6.5	6.5
July 1980	46	46	9.5	9.5	9	9.5
August 1980	48	48	11	10.5	9.5	10
September 1980	46	47	8	9	9	9.5
October 1980	46	46	8	8.5	7.5	7.5
November 1980	42	42	6	6.5	6	6
December 1980	38	38	3.5	3	3.5	3.5
January 1981	42	42	5	5	5	5.5
February 1981	40	40	4.5	4.5	4.5	4.5
March 1981	38	37	3.5	3.5	3	3.5
April 1981	37	36	3	3	4	4
May 1981	41	41	5	5	5	5.5
June 1981	46	46	8	8	8	8.5
July 1981	44	49	9	9	9	9.5
August 1981	53	54	11.5	11.5	12	12.5
September 1981	50	51	10	10	10	10.5

MARYS PEAK SOIL TEMPERATURE DATA

Location: SW¼Sec20T12SR7W

Elevation: 1067 Meters

Aspect: Northerly

% Cover: Closed

Slope: 45%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980	39	39	4.5	5	4.5	4.5
July 1980	44	44	8	8	7.5	7.5
August 1980	47	47	10	10	9.5	9
September 1980	47	47	9	9	9.5	9.5
October 1980	47	47	8.5	8.5	8	8
November 1980	43	43	7	7	6.5	7
December 1980	38	39	3.5	3.5	4.5	4.5
January 1981	45	45	7	7	7	7
February 1981	42	41	5	5	5.5	5
March 1981	39	39	4.5	4.5	4.5	5
April 1981	36	37	2.5	3	3	3
May 1981	40	40	4.5	4.5	4.5	4.5
June 1981	44	44	6.5	6.5	6.5	6.5
July 1981	46	47	8	8	8	8
August 1981	54	54	12	12	12	11.5
September 1981	52	52	11	11	11	11

MARYS PEAK SOIL TEMPERATURE DATA

Location: NW¼Sec28T12SR7W
Elevation: 1219 Meters
Aspect: Southerly
% Cover: Open
Slope: 30%

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors	
					Bead °C	Probe °C
June 1980						
July 1980	46	46	9.5	9.5		
August 1980	50	50	11.5	11.5		
September 1980	50	50	10	10		
October 1980	49	49	10.5	11		
November 1980	44	44	8	8		
December 1980	Snow		Snow			
January 1981						
February 1981						
March 1981	40	40	4	5		
April 1981	Snow		Snow			
May 1981						
June 1981						
July 1981						
August 1981	52	52	11	11		
September 1981	54	54	11.5	11.5		

MARYS PEAK SOIL TEMPERATURE DATA

Location:	NW¼Sec28T12SR7W	Elevation:	1219 Meters
Aspect:	Northerly	% Cover:	Open
Slope:	25%		

Soil Temperature (F°) and (C°) at 50 cm (20 inches) Depth

	Soil Test Thermometer °F		Weston Thermometer °C		Thermistors Bead °C	Thermistors Probe °C
June 1980						
July 1980	48	47	9.5	9.5		
August 1980	50	50	11	11.5		
September 1980	50	50	10.5	10.5		
October 1980	48	48	10	9.5		
November 1980	40	39	6	6		
December 1980	Snow		Snow			
January 1981						
February 1981						
March 1981	36	36	2.5	3.5		
April 1981	Snow		Snow			
May 1981						
June 1981						
July 1981						
August 1981	55	55	12.5	12		
September 1981	54	54	11.5	11.5		

APPENDIX II

Site descriptions, soil classification, and profile descriptions of soils at each site. Symbols used are in accordance with Soil Conservation Service guidelines, as published in draft chapters of the New Soil Survey Manual. The reference is SCS Directive 430-V, Issue 1, 1981.

Horizon	Depth cm	Moist Color Hue Val/CMA	Text.	Struct.	Consistence Dry Moist Wet	pH	Coarse Frag.	Clay Films
	SITE: 305 Meters Southerly Open CLASSIFICATION: Fine Mixed Mesic Typic Haplohumult					SLOPE: 25% RELIEF: Convex		
A1	0 - 7.5	7.5YR 3/3	SiL	2fgr	sh fr ss-ps	6.2	—	—
A2	7.5- 28	7.5YR 3/3	SiCL	2msbk	sh fr s-p	6.0	—	—
BA	28 - 45.5	5YR 3/4	SiCl	2msbk	sh fi s-p	6.0	—	—
Bt1	45.5- 61	5YR 3/4	SiC	2msbk	h fi s-p	5.8	—	1n po 1n discont pf
2Bt2	61 - 96.5	5YR 3/4	SiC	2msbk	h fi s-vp	5.8	20%Pebb	2mk po-pf
2BC	96.5-112	5YR 3/4	SiCL	1msbk	sh fr s-p	5.8	55%coarse frag.	1npo-pf 3kcoarse frag surfaces
3Cr	112 -152.5	5YR 3/4	SiCL	m	sh fr s-p	5.8	75%coarse frag.	3kcoarse frag surfaces
	SITE: 305 Meters Southerly Closed CLASSIFICATION: Fine Silty Mixed Mesic Typic Haplohumult					SLOPE: 28% RELIEF: Convex		
Oi	2.5- 0							
A1	0 - 7.5	7.5YR 2/2	SiL	3fgr	sh fr ss-ps	5.6	3%Pebb	—
A2	7.5- 23	7.5YR 2.5/2	SiL	2fsbk	sh fr ss-ps	5.6	1%Pebb	—
BA	23 - 53	7.5YR 3/4	SiL	2msbk	h fr ss-ps	5.4	1%Pebb	—
Bt1	53 - 73.5	5YR 3/4	SiCL	2msbk	h fr s-p	5.4	1%Pebb	1npf-po
Bt2	73.5- 96.5	5YR 3/4	SiCL	2msbk	h fr s-p	5.4	1%Pebb	1n pf-po
Bt3	96.5-134.5	5YR 3/4	SiCL	2msbk	vh fr s-p	5.4	1%Pebb	1n pf-po
2BCt	134.5-152.5	7.5YR 3/4	SiCL	2msbk	vh fr s-p	5.4	20%soft siltstone	1n pf-po

Horizon	Depth cm	Moist Color Hue Val/CMA	Text.	Struct.	Consistence Dry Moist Wet	pH	Coarse Frag.	Clay Films

SITE: 305 Meters Northerly Open SLOPE: 25%
CLASSIFICATION: Fine Silty Mixed Mesic Typic Haplohumult RELIEF: Convex

Horizon	Depth cm	Moist Color Hue Val/CMA	Text.	Struct.	Consistence Dry Moist Wet	pH	Coarse Frag.	Clay Films
A	0 - 15	5YR 4/3	L	3mgr	sh fr ss-ps	6.2	12%Pebb	_____
AB	15 - 38	5YR 3/3	SiCL	2fsbk	sh fr ss-ps	5.8	5%Pebb	_____
BA	38 - 66	5YR 3/3	SiCL	2fsbk	h fr ss-ps	5.5	5%Pebb	_____
Bt1	66 -112	5YR 3/3	SiCL	2msbk	h fr s-p	5.5	5%Pebb	1n pf-po
Bt2	122 -152.5	5YR 3/4	SiCL	2msbk	h fr s-p	5.5	5%Pebb	3mk pf-po

SITE: 305 Meters Northerly Closed SLOPE: 34%
CLASSIFICATION: Fine Silty Mixed Mesic Typic Haplohumult RELIEF: Convex

Horizon	Depth cm	Moist Color Hue Val/CMA	Text.	Struct.	Consistence Dry Moist Wet	pH	Coarse Frag.	Clay Films
Oi	5 - 0							
A	0 - 13	5YR 3/2	L	3mgr	sh fr ss-ps	6.2	10%Pebb	_____
AB	13 - 38	5YR 3/3	SiCL	2fsbk	sh fr ss-ps	5.8	5%Pebb	_____
BA	38 - 73.5	5YR 3/3	SiCL	2fsbk	sh fr ss-ps	5.6	5%Pebb	_____
Bt1	73.5-114	5YR 3/3	SiCL	2msbk	h fr s-p	5.6	5%Pebb	1n pf-po
Bt2	114 -152.5	5YR 3/4	SiCL	2msbk	h fi s-p	5.6	5%Pebb	3mk pf-po

SITE: 455 Meters Southerly Closed
CLASSIFICATION: Coarse-Silty Mixed Mesic Typic Haplumbrept

SLOPE: 22%
RELIEF: Convex

Horizon	Depth cm	Moist Color Hue Val/CMA	Text.	Struct.	Consistence Dry Moist Wet	pH	Coarse Frag.	Clay Films
Oi	2 - 0							
A1	0 - 7.5	7.5YR 3/3	SiL	1fgr	sh vfr ss-ps	5.4	5%Pebb	—
A2	7.5- 35.5	5YR 3/3	SiL	1fgr	sh vfr ss-ps	5.4	10%Pebb	—
AB	35.5- 58.5	5YR 3/4	SiL	1fsbk	sh fr ss-ps	5.3	10%Pebb	—
Bw	58-5- 91.5	7.5YR 3/4	SiL	2msbk	sh fr ss-ps	5.3	15%Pebb	—
BC	91.5-117	7.5YR 3/4	grSiL	2msbk	sh fi ss-ps	5.2	20%Pebb	—
BC2	117 -152.5	7.5YR 4/6	grSiL	2msbk	sh fi ss-ps	5.2	25%Pebb	—

SITE: 455 Meters Northerly Closed
CLASSIFICATION: Coarse-Loamy Mixed Mesic Typic Haplumbrept

SLOPE: 55%
RELIEF: Convex

Horizon	Depth cm	Moist Color Hue Val/CMA	Text.	Struct.	Consistence Dry Moist Wet	pH	Coarse Frag.	Clay Films
Oi	2.5- 0							
A	0 - 13	7.5YR 3/2	SiL	2fgr	sh fr ss-ps	5.4	10%Pebb	—
AB	13 - 35.5	7.5YR 3/3	SiL	2fsbk	sh vfr ss-ps	5.4	10%Pebb	—
Bw1	35.5- 76	7.5YR 4/3	SiL	2msbk	sh fr ss-ps	5.4	14%Pebb	—
2Bw2	76 -109	10YR 4/4	SL	2msbk	sh fr ss-ps	5.2	55%soft Siltstone	—
2BC	109 -152.5	10YR 4/4	SL	1fsbk	sh vfr so-po	5.2	65%soft Siltstone	—

SITE: 610 Meters Southerly Open
CLASSIFICATION: Loamy-skeletal Mixed Mesic Typic Dystrochrept
SLOPE: 50%
RELIEF: Convex

Horizon	Depth cm	Moist Color Hue	Val/CMA	Text.	Struct.	Consistence Dry Moist Wet	pH	Coarse Frag.	Clay Films
A	0 - 15	10YR	2/2	grL	3fgr	so fr so-po	5.8	30%gr	_____
Bw1	15 - 43	7.5YR	3/4	vgrL	2fsbk	so fr so-po	5.6	40%gr	_____
Bw2	43 - 53	7.5YR	3/4	vgrL	1fsbk	so fr so-po	5.6	80%gr	_____
R									

SITE: 610 Meters Southerly Closed
CLASSIFICATION: Coarse-silty Mixed Mesic Pachic Haplumbrept
SLOPE: 32%
RELIEF: Convex

Horizon	Depth cm	Moist Color Hue	Val/CMA	Text.	Struct.	Consistence Dry Moist Wet	pH	Coarse Frag.	Clay Films
Oi	2.5- 0								
A	0 - 23	7.5YR	3/3	SiL	2mgr	so fr ss-ps	5.4	5%Pebb	_____
AB	23 - 56	5YR	3/3	SiL	2fsbk	so fr ss-ps	5.4	5%Pebb	_____
Bw1	56 -127	7.5YR	4/6	SiL	2msbk	so fr ss-ps	5.4	5%Pebb	_____
Bw2	127 -152.5	7.5YR	4/6	SiL	2msbk	so fi ss-ps	5.4	5%Pebb	_____

Horizon	Depth cm	Moist Color Hue Val/CMA	Text.	Struct.	Consistence Dry Moist Wet	pH	Coarse Frag.	Clay Films
	SITE: 610 Meters Northerly Open CLASSIFICATION: Loamy-skeletal Mixed Mesic Typic Haplumbrept					SLOPE: 32% RELIEF: Convex		
A1	0 - 7.5	10YR 2/2	grL	2vfgr	sh fr ss-ps	5.8	25%Pebb-3%Cobb	____
A2	7.5- 28	10YR 2/2	grL	2vfgr	sh fi ss-ps	5.6	25%Pebb-5%Cobb	____
Bw1	28 - 48	10YR 2/3	grL	1fsbk	sh fi ss-ps	5.6	25%Pebb-15%Cobb	____
Bw2	48 - 81	10YR 3/4	grSiL	1msbk	sh fi ss-ps	5.4	25%Pebb-15%Cobb	____
Bw3	81 -104	10YR 3/4	grSiL	1msbk	sh fi s-p	5.4	25%Pebb-15%Cobb	____
2C	104 -152.5	10YR 3.5/4	vgrSL	m	sh fi ss-ps	5.4	50%Pebb-5%Cobb	____
	SITE: 610 Meters Northerly Closed CLASSIFICATION: Fine-Silty Mixed Mesic Typic Haplumbrept					SLOPE: 12% RELIEF: Convex		
Oi	5 - 0							
A1	0 - 18	10YR 3/2	grSiL	3fgr	sh fr ss-ps	5.6	15%Pebb-10%Cobb	____
A2	18 - 28	10YR 3/3	grSiL	2fsbk	sh fr ss-ps	5.6	15%Pebb-10%Cobb	____
2Bw1	28 - 58.5	10YR 4/4	SiCL	2msbk	sh fr s-p	5.4	7%Pebb-10%Cobb	____
2Bw2	58.5- 86	10YR 4/4	SiCL	2msbk	sh fr s-p	5.4	7%Pebb-20%Cobb	____
2Bw3	86 -109	10YR 4/4	SiCL	2msbk	sh fr s-p	5.4	5%Pebb-3%Cobb	____
2Bw4	109 -152.5	10YR 5/4	SiCL	2msbk	sh fr s-p	5.4	3%Pebb-3%Cobb	____

SITE: 762 Southerly Open
CLASSIFICATION: Loamy-Skeletal Mixed Mesic Pachic Haplumbrept

SLOPE: 37%
RELIEF: Convex

Horizon	Depth cm	Moist Color Hue Val/CMA	Text.	Struct.	Consistence Dry Moist Wet	pH	Coarse Frag.	Clay Films
A1	0 - 7.5	10YR 2/2	vgrSiL	3fgr	sh fr ss-ps	5.6	40%Pebb	_____
A2	7.5- 53	10YR 3/3	vgrSiL	1fsbk	sh fr ss-ps	5.6	45%Pebb	_____
Bw1	53 - 81	10YR 5/4	vgrL	1fsbk	sh fr ss-ps	5.4	35%Pebb	_____
Bw2	81 -112	10YR 4/4	exgrL	1msbk	sh fr ss-ps	5.4	35%Pebb-30%Cobb	_____
R								

SITE: 762 Meters Southerly Closed
CLASSIFICATION: Loamy-Skeletal Mixed Mesic Typic Haplumbrept

SLOPE: 35%
RELIEF: Convex

Horizon	Depth cm	Moist Color Hue Val/CMA	Text.	Struct.	Consistence Dry Moist Wet	pH	Coarse Frag.	Clay Films
Oi	5 - 0							
A	0 - 40.5	10YR 2/2	vgrSiL	3fgr	sh fr ss-ps	5.4	45%Pebb	_____
AB	40.5- 73.5	10YR 3/6	vgrSiL	1fsbk	sh fr ss-ps	5.4	49%Pebb-1%Cobb	_____
Bw1	73.5-107	10YR 4/4	exgrSiL	2fsbk	sh fr ss-ps	5.2	65%Pebb	_____
Bw2	107 -152.5	10YR 4/4	exgrSiL	1fsbk	sh fr ss-ps	5.2	80%soft Siltstone	_____

SITE: 762 Meters Northerly Open
CLASSIFICATION: Coarse-Loamy Mixed Typic Cryumbrept

SLOPE: 63%
RELIEF: Convex

Horizon	Depth cm	Moist Color		Text.	Struct.	Consistence			pH	Coarse Frag.	Clay Films
		Hue	Val/CMA			Dry	Moist	Wet			
A1	0 - 13	10YR	2/2	grSiL	3fgr	sh	fr	so-po	5.4	30%Pebb	_____
A2	13 - 43	10YR	2/2	grSiL	1fsbk	sh	fr	so-po	5.4	34%Pebb	_____
Bw1	43 - 66	10YR	3/4	grSiL	1fsbk	sh	fr	ss-ps	5.3	34%Pebb	_____
Bw2	66 - 99	10YR	3/4	grSiL	2fsbk	sh	fr	ss-ps	5.3	30%Pebb-3%Cobb	_____
R											

SITE: 762 Meters Northerly Closed
CLASSIFICATION: Coarse-Silty Mixed Frigid Typic Haplumbrept

SLOPE: 35%
RELIEF: Convex

Horizon	Depth cm	Moist Color		Text.	Struct.	Consistence			pH	Coarse Frag.	Clay Films
		Hue	Val/CMA			Dry	Moist	Wet			
Oi	7.5- 0										
A	0 - 18	7.5YR	2/2	SiL	3fgr	sh	fr	ss-ps	5.8	25%soft Siltstone	_____
AB	18 - 43	7.5YR	3/3	SiL	2fsbk	sh	fr	ss-ps	5.8	25%soft Siltstone	_____
Bw1	43 - 89	7.5YR	4/6	SiL	1msbk	sh	fr	ss-ps	5.6	10%Soft Siltstone	_____
2Bw2	89 -112	10YR	4/3	SiL	1fsbk	sh	fr	ss-ps	5.4	30%Soft Siltstone	_____
3Cr	112 -152.5										

Horizon	Depth	Moist Color		Text.	Struct.	Consistence	pH	Coarse	Clay
	cm	Hue	Val/CMA			Dry Moist Wet		Frag.	Films
	SITE: 914 Meters Southerly Open CLASSIFICATION: Loamy-Skeletal Mixed Mesic Typic Haplumbrept						SLOPE: 52% RELIEF: Convex		
A1	0 - 7.5	10YR	2/2	vgrL	1vfgr	sh fr ss-ps	5.8	45%Pebb-5%Cobb	_____
A2	7.5- 35.5	10YR	3/2	vgrL	1msbk	sh fr ss-ps	5.8	45%Pebb-15%Cobb	_____
Bw	35.5- 71	7.5YR	3/4	vgrL	1msbk	sh fr ss-ps	5.6	40%Pebb-15%Cobb	_____
R									
	SITE: 914 Meters Southerly Closed CLASSIFICATION: Loamy-Skeletal Mixed Frigid Typic Haplumbrept						SLOPE: 52% RELIEF: Convex		
Oi	5 - 0								
A1	0 - 7.5	10YR	2.5/2	grL	2fgr	so fr ss-ps	5.6	30%Pebb	_____
A2	7.5- 30.5	10YR	2.5/2	vgrL	1msbk	so fr ss-ps	5.4	30%Pebb-10%Cobb	_____
Bw	30.5- 66	10YR	4/3	vgrL	1msbk	so fr ss-ps	5.4	30%Pebb-20%Cobb	_____
R									

Horizon	Depth cm	Moist Color Hue	Val/CMA	Text.	Struct.	Consistence Dry Moist Wet	pH	Coarse Frag.	Clay Films
	SITE: 914 Meters Northerly Open CLASSIFICATION: Loamy-Skeletal Mixed Typic Crymbrept						SLOPE: 70% RELIEF: Convex		
A	0 - 25	10YR	2/2	grSiL	3fgr	sh fr ss-ps	6.2	30%gr	_____
AB	25 - 81	10YR	3/2	grSiL	2fsbk	sh fr ss-ps	6.2	25%gr	_____
2Bw1	81 -119	10YR	3/4	exgrL	1fsbk	sh fr so-po	6.2	70%gr	_____
2Bw2	119 -152.5	10YR	3/4	exgrL	1fsbk	sh fr so-po	6.2	70%gr	_____
	SITE: 914 Northerly Closed CLASSIFICATION: Coarse-Loamy Mixed Frigid Typic Haplumbrept						SLOPE: 40% RELIEF: Convex		
Oi	5 - 0								
A1	0 - 20	10YR	2/2	grSiL	2fgr	sh fr ss-ps	5.6	15%gr	_____
A2	20 - 40.5	10YR	2/2	grSiL	1fsbk	sh fr ss-ps	5.6	15%gr	_____
Bw	40.5- 86	10YR	3/4	SiL	2fsbk	sh fr ss-ps	5.6	10%gr	_____
BC	86 -109	10YR	3/4	L	2msbk	sh fr so-po	5.6	5%gr	_____
BC2	109 -119	10YR	6/4	excobSL	2msbk	sh fr so-po	5.6	50%Cobb	_____
R									

Horizon	Depth	Moist Color		Text.	Struct.	Consistence			pH	Coarse	Clay
	cm	Hue	Val/CMA			Dry	Moist	Wet		Frag.	Films
	SITE: 1067 Meters Southerly Open CLASSIFICATION: Medial-Skeletal Typic Cryandept								SLOPE: 5% RELIEF: Convex		
A1	0 - 7.5	10YR	2/1	SiL	2fgr	so	vfr	so-po	4.8	2%Pebb-5%Cobb	_____
A2	7.5- 43	10YR	2/2	cobSiL	2fsbk	so	fr	so-po	4.8	4%Pebb-30%Cobb	_____
Bw	43 - 63.5	10YR	2/2	excobSiL	2fsbk	so	fr	so-po	4.8	10%Pebb-60%Cobb	_____
R											
	SITE: 1067 Meters Southerly Closed CLASSIFICATION: Medial-Skeletal Typic Cryandept								SLOPE: 35% RELIEF: Convex		
Oi	5 - 0										
A1	0 - 10	10YR	2/2	grSiL	2vfgr	so	fr	ss-ps	5.6	20%Pebb-5%Cobb	_____
A2	10 - 53.5	10YR	2/2	vgrSiL	1msbk	so	fr	ss-ps	5.4	30%Pebb-20%Cobb	_____
Bw	53.5- 81	10YR	3/4	vgrL	1msbk	so	fr	ss-ps	5.4	30%Pebb-20%Cobb	_____
R											

Horizon	Depth	Moist Color		Text.	Struct.	Consistence	pH	Coarse	Clay
	cm	Hue	Val/CMA			Dry Moist Wet		Frag.	Films
	SITE: 1067 Meters Northerly Open CLASSIFICATION: Medial Typic Cryandept						SLOPE: 45% RELIEF: Convex		
A1	0 - 7.5	10YR	2/1	SiL	2fgr	so vfr so-po	5.4	5%Pebb-5%Cobb	_____
A2	7.5- 35.5	10YR	2/1	cobSiL	3fsbk	so vfr so-po	5.4	7%Pebb-10%Cobb	_____
AB	35.5- 63.5	10YR	2/2	cobSiL	2msbk	so vfr so-po	5.4	10%Pebb-16%Cobb	_____
BA	63.5-101.5	10YR	2/3	cobSiL	2msbk	so vfr so-po	5.4	10%Pebb-15%Cobb	_____
Bw1	101.5-124.5	10YR 10YR	3/4 & 4/4	vcobSiL	2msbk	so vfr so-po	5.2	15%Pebb-30%Cobb	_____
Bw2	124.5-152.5	10YR 10YR	3/4 & 4/4	vcobSiL	1msbk	so vfr so-po	5.2	20%Pebb-35%Cobb	_____
	SITE: 1067 Meters Northerly Closed CLASSIFICATION: Medial-Skeletal Typic Cryandept						SLOPE: 45% RELIEF: Convex		
Oi	2.5- 0								
A1	0 - 7.5	10YR	2/1	grSiL	3fgr	so fr ss-ps	5.6	15%Pebb	_____
A2	7.5- 43	10YR	2/1	grSiL	2fsbk	so fr ss-ps	5.6	15%Pebb	_____
BA	43 - 68.5	10YR	2/4	grSiL	2msbk	so fr ss-ps	5.4	15%Pebb-5%Cobb	_____
2Bw1	68.5-101.5	10YR	6/4	excobSiL	1msbk	so fr ss-ps	5.4	25%Pebb-40%Cobb	_____
3Bw2	101.5-132	10YR 10YR	4/4 & 8/1	excobSiL	1fsbk	so fr ss-ps	5.4	25%Pebb-60%Cobb	_____
R									

Horizon	Depth cm	Moist Color Hue Val/CMA	Text.	Struct.	Consistence Dry Moist Wet	pH	Coarse Frag.	Clay Films
	SITE: 1219 Meters Southerly Open CLASSIFICATION: Medial Typic Cryandept					SLOPE: 30% RELIEF: Convex		
A1	0 - 23	10YR 2/1	SiL	2fgr	so vfr so-po	4.8	5%Pebb	___
A2	23 - 50	10YR 2/1	SiL	2fsbk	so vfr so-po	4.6	10%Pebb	___
Bw	50 - 68.5	10YR 2/3	vgrSiL	2msbk	so vfr so-po	4.6	25%Pebb-25%Cobb	___
R								
	SITE: 1219 Meters Northerly Open CLASSIFICATION: Medial Typic Cryandept					SLOPE: 25% RELIEF: Convex		
A1	0 - 18	10YR 2/1	SiL	2fgr	sh vfr so-po	5.2	2%Pebb-5%Cobb	___
A2	18 - 35.5	10YR 2/1	cobSiL	2fsbk	sh vfr so-po	5.2	10%Pebb-20%Cobb	___
Bw	35.5- 61	10YR 2/2	cobSiL	2fsbk	sh vfr so-po	5.2	15%Pebb-25%Cobb	___
R								