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CLIMATIC CLASSIFICATIONS OF THE PRAIRIE PROVINCES: A NEW PRELIMINARY CLASSIFICATION FOR THE FORESTED AREA OF ALBERTA

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Thornthwaite[22] stated that the purpose of any climatic classification is to provide a concise description of the various climatic types in terms of the truly active factors. A classification should not only differentiate between types, but should also show the relationships among them. At the same time it should supply the framework for differentiation of the innumerable microclimates that make up a climatic type.

Various climatic or related classifications have been produced for all, or portions of, the Prairie Provinces. Many of these classifications have been oriented to discipline such as agriculture and soils, or have included non-subjective biases to vegetation or physiographic features. Many of these classifications lack the detail desired for management; a whole province is often classified into only two or three zones, and the forested zone is rarely subdivided. Forest management and related forest research agencies require climatological information and climatic classification to assess productivity of forest land use and to conduct and apply research in forest management. A preliminary study of a portion of Alberta was initiated in 1969--and expanded in 1971 to include the three Prairie Provinces--to classify forested areas having similar summer climatic regimes based solely on climatic variables and their interactions without reference to vegetation and other features. The study was restricted to the summer period, May to September, because it is the growing season, and because year-round climate stations in the forested zones are scarce.

CLIMATIC CLASSIFICATIONS

Existing climatic classifications for the Prairie Provinces are generally inadequate for the forested regions which comprise over three-quarters of their area (Figure 1).[19] Some climatic classifications have been based on features of general climate rather than on quantitative values for different climatic parameters. Examples of such classifications for the area are those of Taylor,[21] and Kendrew and Currie.[8] Köppen, the father of modern climatic classification, accepted the hypothesis that climate is reflected by the distribution of vegetation. In this initial

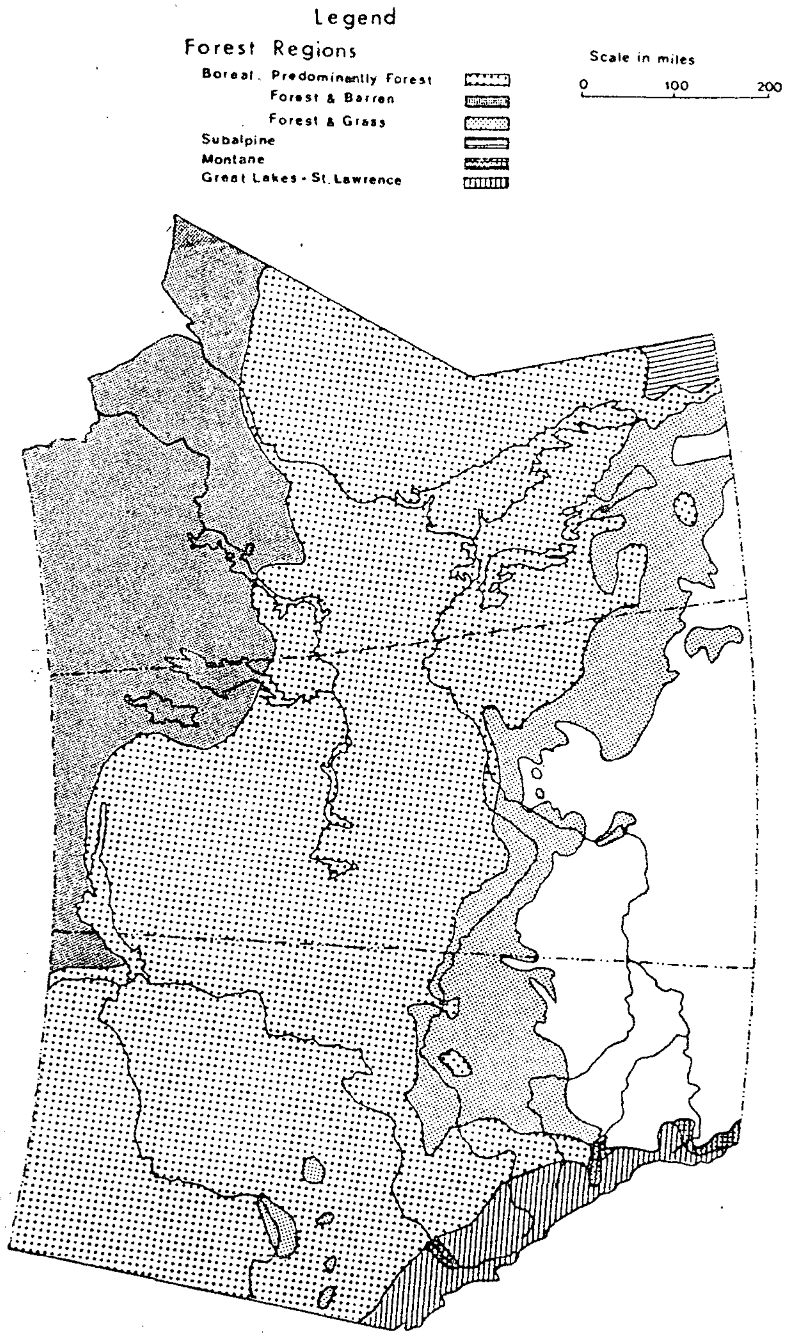


Figure 1. Forest regions of the Prairie Provinces (after Rowe 1972)

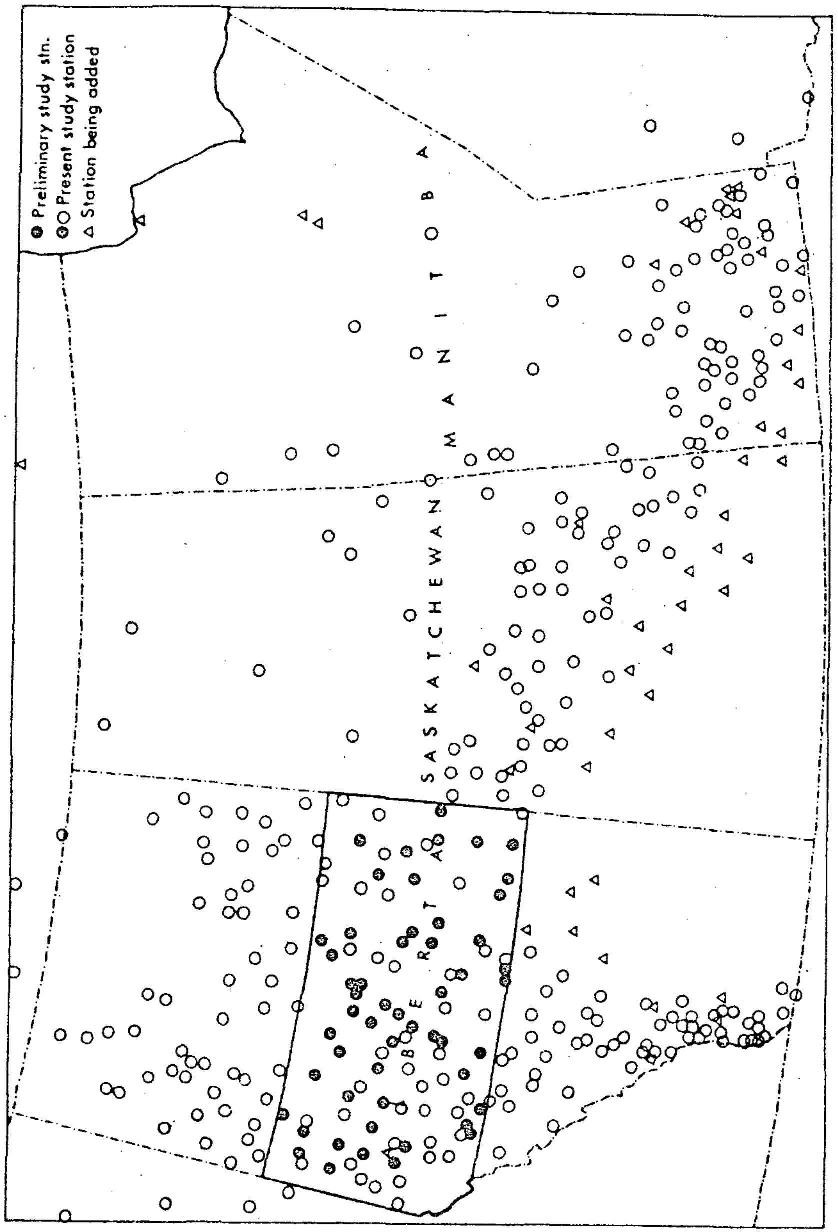
and subsequent classifications,[10,11,12] he attempted to delineate different vegetation boundaries by means of quantitative averages of climatic parameters. Köppen's classification has often been applied to all or portions of the area on the basis of different 30-year normal periods.[5,13,18] Most of the area falls into Köppen's Humid microthermal climate, *D*, but portions southeast Alberta and southwest Saskatchewan fall into his Dry climate region (*Bsk* Middle latitude steppe or Cold steppe). The forested area of the *D* climate falls into his *Dfc* region (Sub-Arctic or Cold 'snowy forest' climate). The remainder of the *D* climate--in the parkland and prairie area--falls into his *Dfb* region (Humid continental, cool summer, no dry season, or Cold 'forest,' cool summer).

Others, such as Rheumer[17] and Trewartha[24] have modified Köppen's classifications and applied them to more restricted areas. Maps of climatic regions, natural vegetation, and zonal soils from the Atlas of Saskatchewan[18] show how closely such different classifications are related.

Thornthwaite's[23] more sophisticated, rational, system of classification follows from the relationship between computed actual evapotranspiration, water surplus, and water deficiency. Sanderson[20] employed Thornthwaite's system to establish climatic types for Canada. The Atlas of Saskatchewan[18] contains an example of moisture regions for Saskatchewan based on the Thornthwaite system. Climatic classifications in more detail exist for the agricultural areas of the Prairie Provinces but like many other classifications they only provide one or two zones for the forested area.[2,6,16,26] Watts, and Chapman and Brown, provided thermal and moisture classes for the area using Thornthwaite's system, and combined the two classes to develop climatic regions or climatic capability classes for agriculture. Thornthwaite's system, despite many features which are better Köppen's classification, is not so easy to employ or to establish boundaries. A provisional soil climate map indicating temperature and moisture regimes and providing considerable detail such as the forested area[4] is based on very little actual data because the necessary parameters have been recorded at only a few locations. Collection of data has commenced only recently at one or two points in the forested zones.

METHODS AND MATERIALS

A portion of Alberta was chosen for the preliminary study which used daily temperature and precipitation data for 54 stations from May 1 to September 30, 1954-1968. This study has been briefly outlined by MacIver *et al.*;[15] greater details of the methodology and approach are recorded elsewhere.[14] Figure 2 shows the preliminary study area and the stations used in the study of the Prairie Provinces. The ten-year period, 1961-1970, considered satisfactory for the latter study was chosen rather than a 30-year 'normal' period because evidence suggested that a 10- to 15-year period would give reliable results from this type of study.[3,7] Data from more stations, especially for the forested area, were available in the most recent period. All stations with six or more years of daily summer temperature and precipitation data, 1961-1970, were included. A few stations with only four or five years of record were included to fill large gaps in the geographical distribution of stations especially gaps in northern Saskatchewan and Manitoba where the recording network is relatively sparse and where precipitation is often recorded only by a climatological or forest fire weather station. The number of stations initially



selected for inclusion in the fringe area--predominantly agricultural--was limited by financial consideration. A total of 343 stations were selected: 205 in Alberta, 60 in Saskatchewan, 68 in Manitoba, and 10 outside the Prairie Provinces. Another 45 stations, recently added mainly from the parkland-prairie grassland fringe area, have not yet been included in the data bank for analysis.

The stages of analysis are shown in Figure 3. Although details of each stage are presented elsewhere,[14,15] some changes have been made for this study. In the preliminary analysis, 75 input variables were calculated for each station. The number of independent input variables has been reduced in the present study to 22. Many of the monthly values have been grouped as seasonal variables; variables showing a high dependence on other variables in the original matrix, or variables that gave a negligible value at all stations (e.g., May water deficiency), have been dropped. Factor analysis, a method to reduce large numbers of input indices to a smaller number of significant indices, and to develop eigenvalues and eigenvectors, was applied to the variables, elevation, longitude, latitude, mean monthly temperature (May to September), total monthly precipitation (May to September), and water deficiency (June to September). Water deficiency and potential evapotranspiration were calculated with slight modifications from the Thornthwaite system. Thornthwaite's formulae were adjusted for a 7-month period; soil moisture storage was assumed to be 4 inches per year at the end of March.[14] A Hierachical Profile Grouping procedure[25] was used instead of the algorithmic grouping procedure employed in the preliminary study. The Hierarchical Program compares a series of factor score profiles (over a series of variables) and progressively associates them into groupings to minimize an overall estimation of variation within the cluster or group.

Analysis was carried out in two phases because of difficulty experienced in integrating climatic data from different Alberta sources. Analysis in the first phase, therefore, was restricted to the Saskatchewan-Manitoba data; there was also less need to generate missing daily data than in the second phase which involved analysis of Alberta data and is the basis for the following results. The base data for the two areas have not yet been run together.

RESULTS AND DISCUSSION

Figure 4 shows the location of the 210 stations initially considered for the Alberta portion of the study and the stations contributing data for the polynomial regression analyses. Third-order polynomial regression coefficients, used to generate missing data for temperature, precipitation, and frequency of days above 28°F values, have the following format:

$$Y = a + b_1x_2 + b_2x^2 + b_3x^3$$

where Y represents the station with missing data, and x represents the complete data of the base station. Thermal variables were predicted quite accurately and were well above the acceptable F value in the analysis of variance tests applied to each regression. Curvilinear regression estimation techniques, however, do not so accurately predict precipitation totals because of the greater variability of location and frequency of rainfall. Of the 91 stations for which regression and analysis of variance tests were performed on each of the three variables, 38 stations failed to satisfy the

PROGRESSION OF ANALYSIS

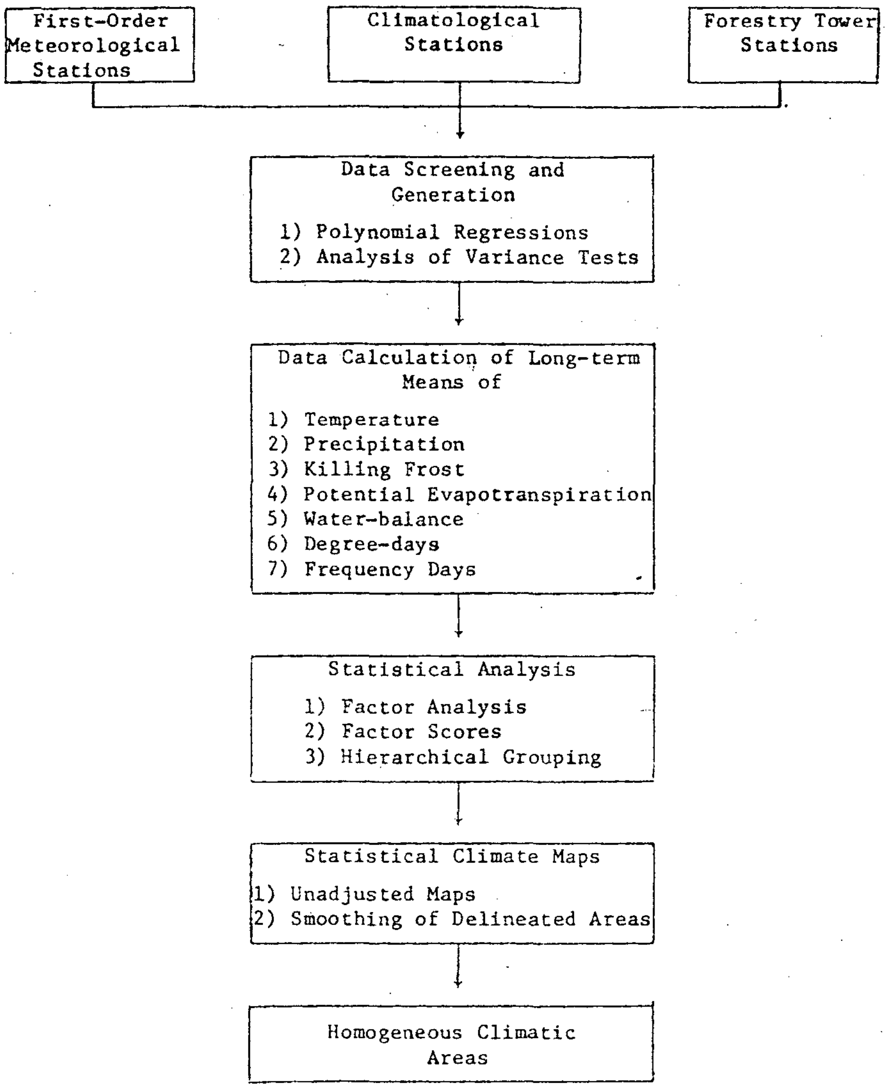


Figure 3. Simplified Flow Chart of Analytical Procedures

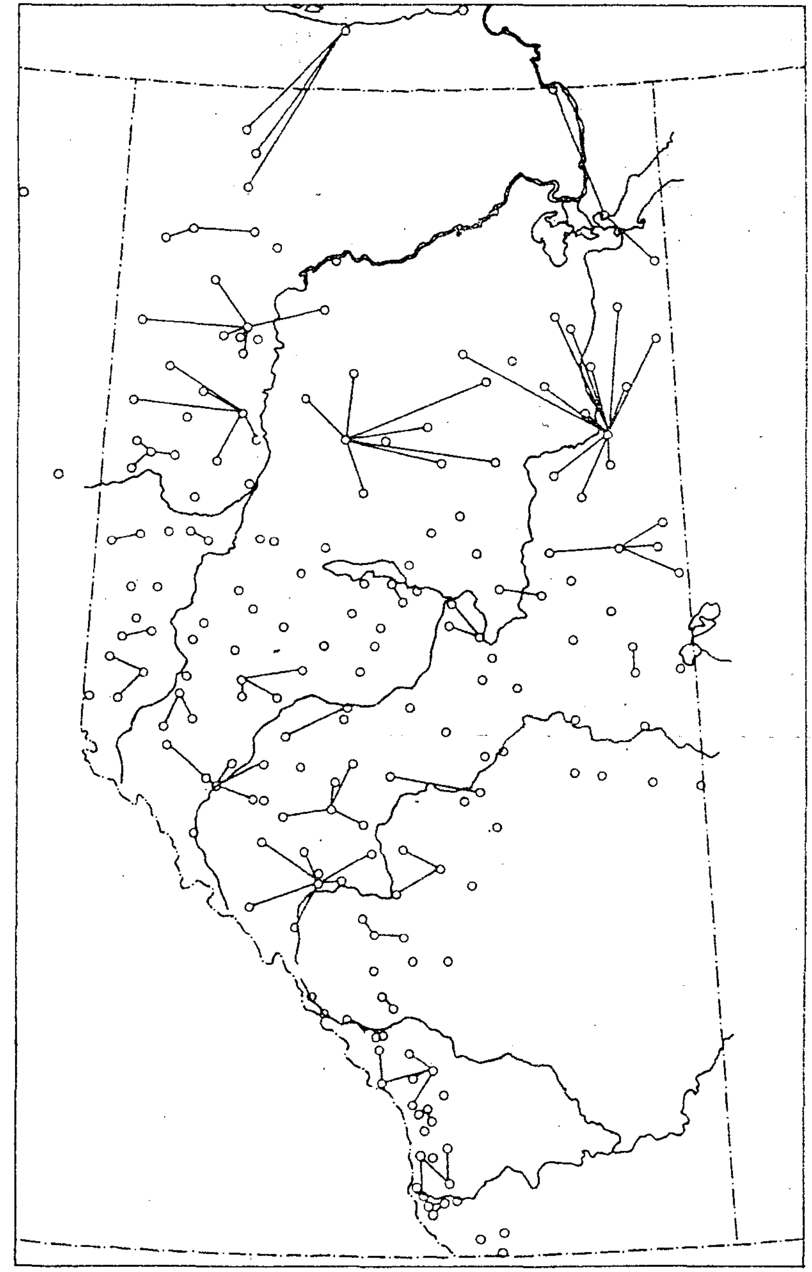


Figure 4. Location of Alberta Stations, including those used in Polynomial Regression.

F ratio requirements of the 95% significance level usually because of poor predictions of precipitation. These stations were then eliminated from further analysis but may be included in future research after completion of further regression computations using different complete base data sets, or using isohyetal or other techniques of estimation.

The factor analysis with 22 input variables yielded seven factors accounting for 80% of the total variance, and ten factors accounting for 85% of the total variance. Because they have an eigenvalue greater than 1.0, only the first five factors (Table 1) are considered.[9] Any inter-relations inherent in the original input indices are represented at this point as independent orthogonal factors. Orthogonality, or rotation of

Table 1

The Five Most Important Factors in the New Preliminary Climate Classification

Factor	Variables	Explained % Total Variance
Factor 1	May-Aug. temperature May freq. of days > 28°F Elevation	25.0
Factor 2	May, June precipitation Latitude Elevation	15.8
Factor 3	July, Aug. precipitation Aug. water deficiency	14.6
Factor 4	June-Sept. freq. of days > 28°F	13.7
Factor 5	Sept. precipitation Sept. water deficiency	4.2

the axis, provides a set of factors "which has the property that any given factors will be fairly highly correlated with some indices (coefficients of the factor matrix) but uncorrelated with the rest."[1] The coefficients of the factors generated orthogonally independent indices per station in the form of factor scores which were then used as input for the Hierarchical Profile Grouping Program. The statistically optimum grouping points, shown in Figure 5, represent the groupings of minimum accumulated errors as progressive groupings of stations into fewer and fewer groups evolve from the hierarchical program. The fewer the number of groups, the greater the error accumulated.

The optimal number of groups for delineating climatic regions for Alberta--28 and 15 groups--are plotted on maps for Alberta, Figures 6 and 7 (the numbers on the figures have no significance except that they relate to groups of the hierarchical program). These are preliminary maps which may change when the data base is expanded to include more stations, and when data from the three Prairie Provinces are combined. However, the forested areas are divided into a number of statistically stable summer climatic regions more useful for classification and detailed management

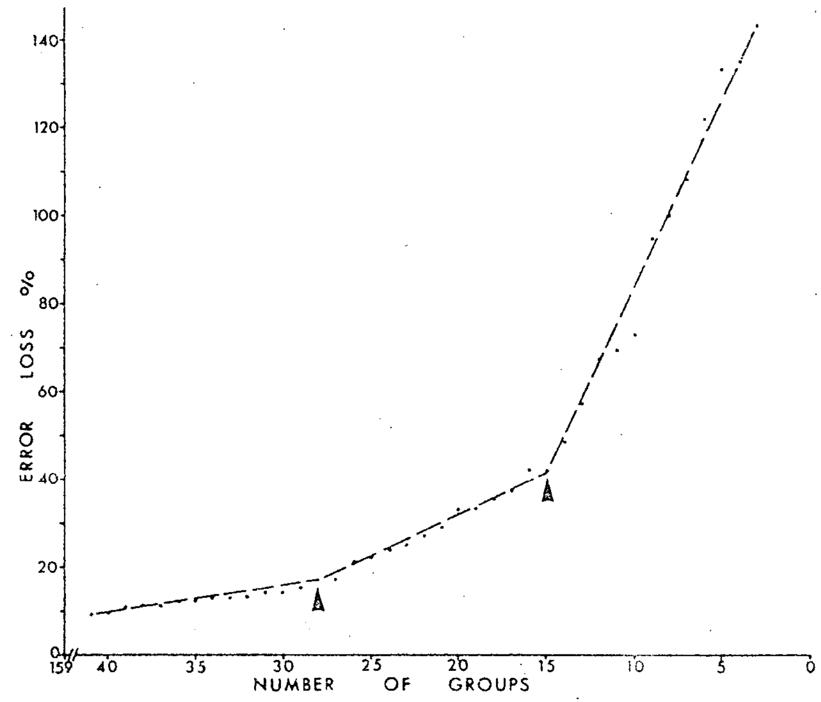


Figure 5. Graph of Hierarchical Groupings and Optimal Grouping Points

programs than prior classifications. Certain stations at present may not be representative of surrounding regions and data from them must be further validated. A final statistical climate map for the forested areas of the Prairie Provinces will be assessed in terms of earlier climatic classifications, and in relation to forest cover and other biological and physical criteria.

The hierarchical grouping method--not used in the preliminary study--is very adaptable; maps can be drawn for any number of groups, and relation of groups to one another are shown. The system itself is very flexible because small areas can be analysed separately and new data for analysis can be added to the system. Maps can be drawn of each of the climatic input variables for the area thereby permitting a large volume of ancillary data to be developed from the system, and from analysis of it. The final stage in the analysis will be the construction of a classification model utilizing the predetermined class limits established by this classification.

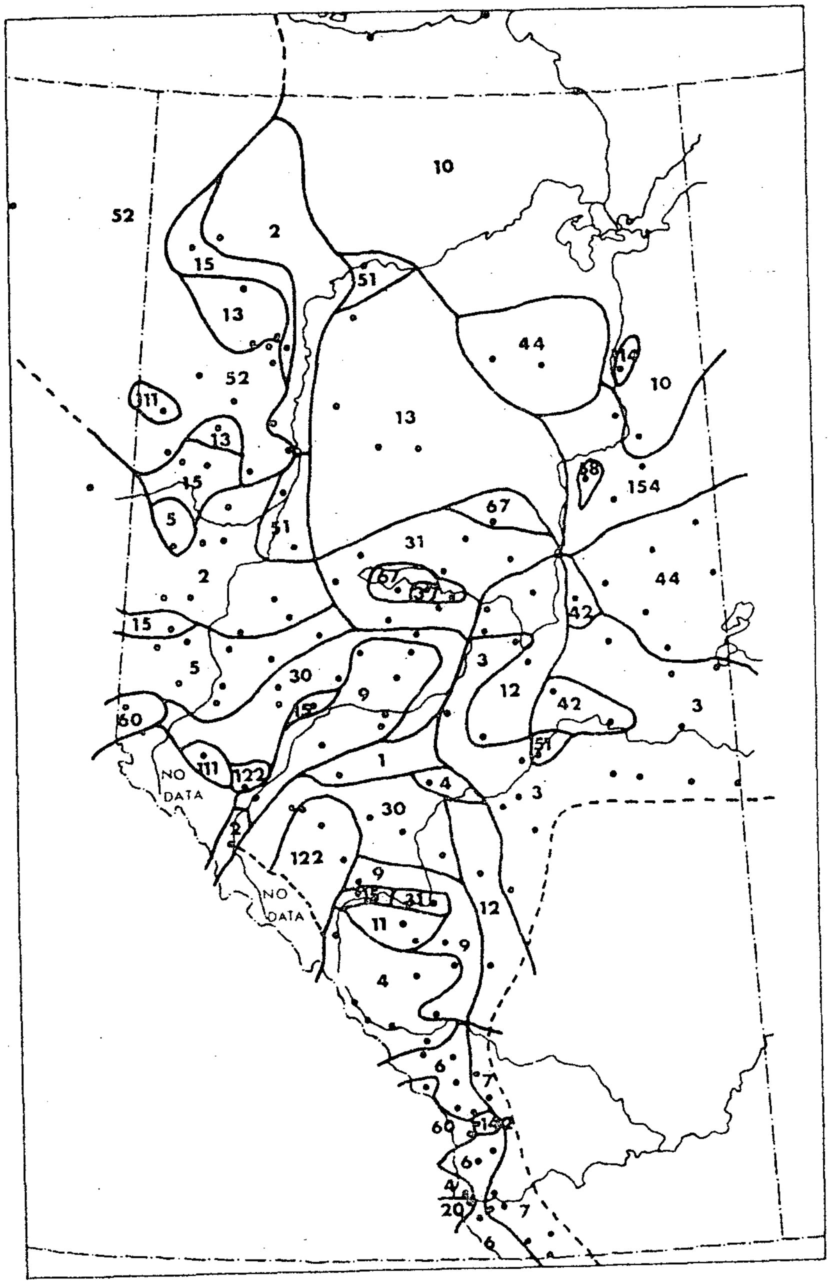


Figure 6. Summer Climatic Zones of Alberta with 28 Groups (numbers relate to groupings of the hierarchical program).

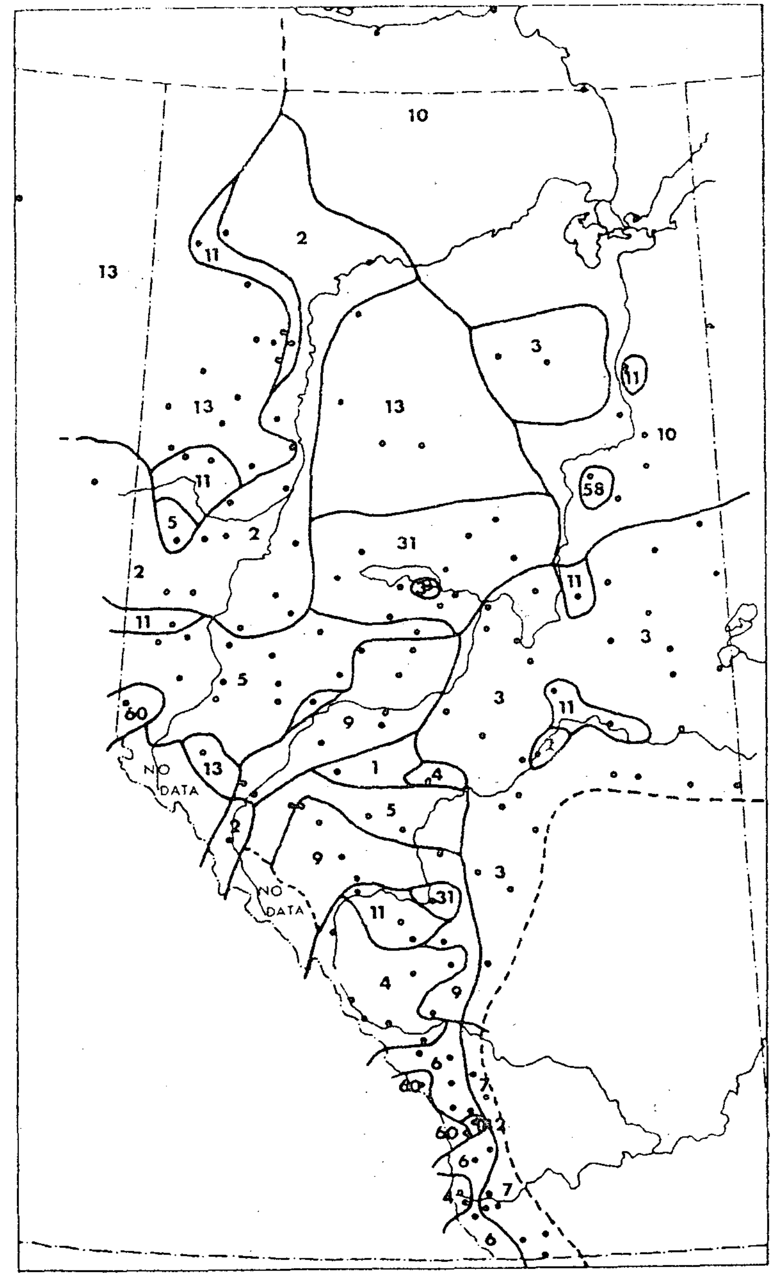


Figure 7. Summer Climatic Zones of Alberta with 15 Groups (numbers relate to groupings of the hierarchical program).

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