# THE ECOLOGICAL LIFE ZONES OF OREGON:
# A TEST OF THE HOLDRIDGE MODEL

by

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ABSTRACT. The Holdridge model of ecological classification is applied to the state of Oregon resulting in a life zone map. Vegetation maps are employed to evaluate the units defined by the model. The life zone map collates with vegetation maps and the patterns appear quite rational.

# THE ECOLOGICAL LIFE ZONES OF OREGON: A TEST OF THE HOLDRIDGE MODEL

## I. INTRODUCTION

The intricate interrelationships of climate, topography, soils, and vegetation were described by the naturalist Von Humboldt in the early nineteenth century:

> Nature presents the phenomenon [vegetation] of these wide plains in all zones; but, they have a peculiar character in each of them; a distinct physiognomy which is determined by the diversity of their soils, their climate, and their elevation above sea level.[1]

Postulating the prevalence of macroclimatic conditions over other factors comprising the environment, the Holdridge model of life zone classification is an attempt to differentiate environmentally equivalent units over the terrestrial portions of the earth. The objectives of this study are threefold: 1) to determine whether or not the Holdridge classification scheme provides a satisfactory approach to mapping ecological patterns in Oregon; 2) to prepare a background for further studies; and 3) to give scientists working in the fields of ecology and geography a tool for analyzing ecological factors within the state of Oregon.

The reasons for humanity's seemingly insatiable quest to classify phenomena are not fully understood. The question why

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1 E. Fischer, R. D. Campbell, and E. S. Miller, <u>A Question of Place</u> (Arlington, Va.: R. W. Beatty, Ltd., 1967), p. 65.

classify could be debated for aeons with no complete answer. Nonetheless, concerning this very issue Shimwell has proposed:

> For the human race, classification is a natural and inherent, intuitive process; to create some semblance of order from an otherwise disorderly matrix by the pigeon-holing and categorization of the matrix entities. [2]

To provide a background for discussing the Holdridge model, climatic and vegetation classification schemes, representing various approaches, are first reviewed in this presentation. The life zone classification is then presented in detail and compared with other classificatory systems.

The state of Oregon has been adopted for this study because it offers a challenging test of the Holdridge system in middle latitudes. The test of the model has consisted of: 1) applying the Holdridge classification to Oregon at the life zone level; 2) compiling a life zone distribution map of Oregon; and 3) evaluating this map by comparisons with existing Oregon vegetation distribution maps.

The final section of this paper presents suggestions for continuing application and examination of the Holdridge model. Recommendations concerning other means of map compilation and methods for possible statistical evaluations of the life zone map are proposed.

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2 D. W. Shimwell, The Description and Classification of Vegetation (Seattle: University of Washington Press, 1971), p. 42.

# II. CLIMATIC CLASSIFICATION

In order to obtain an efficient arrangement of the earth's various climatic conditions, science has long sought to devise schemes of classification whereby areas of relative climatic homogeneity might be described and delimited. Several different methods of organization have been developed for this purpose, most of which, according to Wilson, can be grouped into the following two categories: 1) empirical classifications based, for example, on climatic parameters; and 2) genetic classifications which relate causative factors such as air mass circulation to climatic realms.[3] Examples representing each of these categories will be reviewed briefly.

## A. Empirical Classifications

The torrid, temperate, and frigid zones defined by the ancient Greeks is an illustration of an early attempt to categorize world climates, but it was not until Wladimir Köppen presented a quantitative empirical classification system in 1900 that a comprehensive procedure for organizing climates first appeared. Based chiefly upon correspondence with the world vegetation groups developed by de Candolle (1874), the Köppen classification scheme numerically defines the limits of climatic regions in terms of mean temperature

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3 L. Wilson, "Climatic Classification," in R. W. Fairbridge (Ed.), The Encyclopedia of Atmospheric Sciences and Astrogeology, Vol. II (New York: Reinhold Publishing Co., 1967), p. 172.

and precipitation values. Revised and modified a number of times since its introduction, it employs letter codes to designate five principal types of climate as well as seasonal characteristics of rainfall and temperature.

In that Thornthwaite's first climatic classification scheme (1931): 1) attempts to quantitatively define climatic boundaries from empirical data; 2) utilizes letter codes to designate climatic types; and 3) is based primarily upon vegetation, it basically resembles the Köppen system. However, to enable a better measure of the availability of moisture and the effectiveness of temperature as related to plant growth, Thornthwaite introduces two expressions in his early classification. First is precipitation efficiency, a function of precipitation and temperature; second is thermal efficiency, the departure of mean monthly temperatures from the freezing level.

Thornthwaite's 1948 classification system, although still empirical in nature, differs from the first by employing indices determined completely independent of vegetation distribution or plant growth. Six primary climatic types are determined from the mathematical analysis of climatic data (temperature and precipitation) to obtain values for potential evapotranspiration and a moisture index.

Budyko (1956) uses an approach similar to Thornthwaite's second classification scheme. Rather than using temperature values, however, Budyko substitutes net radiation to obtain his climatic indices.

## B. Genetic Classifications

Two schemes representing attempts to classify climates by genetic factors are those of Flohn (1950) and Strahler (1965). Flohn's system, based on global wind belts and precipitation characteristics, divides the earth into eight climatic types. The classification by Strahler is structured primarily in terms of air mass source regions and the nature and movement of frontal systems.

## III. VEGETATION CLASSIFICATION

The principal aims in the classification of vegetation have been summarized by Fosberg:

> Classification of vegetation has as primary objectives to facilitate recording of information in an orderly manner to aid in storage and prompt recovery of such information, to make possible intelligent discussion of vegetation at various levels of abstraction, to aid in understanding the phenomenon itself, and to enable us to communicate information on vegetation easily and unambiguously.[4]

A number of approaches have been utilized in structuring vegetation classification schemes. The task of categorizing the myriad of classification systems according to their approach, however, is complicated because: many schemes use two or more of the basic approaches; and the literature is frought with semantic difficulties concerning the precise definitions of the various approaches. Nevertheless, the following four principal means of classifying vegetation will be used as a basis for this discussion: 1) physiognomic; 2) floristic; 3) ecologic; and 4) combinations. These will be examined individually with representative examples depicting each.

### A. Physiognomic Classifications

Physiognomy is "the appearance, especially the external appearance, of the vegetation..."[5] One of the earliest class-

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4 F. R. Fosberg, "A Classification of Vegetation for General Purposes," in G. F. Peterken _Guide to the Check Sheet for IBP Areas_ (London: Blackwell Scientific Publications, 1967), p. 74.

5 Fosberg, _op. cit._, footnote 4, p. 76.

ifications of vegetation, Schimper's scheme (1898), is based essentially on physiognomy. It defines fifteen major vegetation formations by their gross compositional features. More recently the physiognomic classification of Küchler (1947,1949) provides a scheme whereby categories defined by vegetation forms are symbolically represented by letters. Amendments to this system and a map of the "potential natural vegetation" of the United States were produced by Küchler in 1966.

## B. Floristic Classifications

The floristic approach to vegetation classification "deals with individual species..." and "considers the kinds of plants of which vegetation consists."[6] The Braun-Blanquet method is an example of classifying vegetation floristically. This system establishes a vegetation hierarchy through the detailed examination of the flora within a study area.

## C. Ecologic Classifications

In the ecological classification scheme, vegetation types are grouped by "the kind of environment in which they occur."[7] An illustration of this avenue to categorization is that of Gaussen (1948) who integrates vegetation and habitat conditions into what he terms "plant climates." Daubenmire also favors an ecologic approach in his classification of vegetation zones in

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6 A. W. Küchler, "Classification and Purpose in Vegetation Maps," Geog. Review, Vol. 46 (1956), pp. 159 - 160.

7 A. W. Küchler, Vegetation Mapping (New York: Ronald Press Co., 1967), p. 56.

the Rocky Mountains (1943). Six major zones are distinguished by "the nature of the climatic climax associations which obtain at different elevations or in different regions."[8]

## D. Combination Approaches to Classification

One important system that employs a combination of methods in classifying vegetation is that by Shantz and Zon (1923). They use a "biological unit" as a basis for categorizing and mapping the vegetation of the United States. In reviewing the Shantz and Zon scheme, Küchler comments:

> This excellent map [and classification] combines the regional, physiognomic, floristic, and ecological approaches by using each one wherever it seems the most useful.[9]

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8 R. F. Daubenmire, "Vegetation Zonation in the Rocky Mountains," Botanical Review, Vol. 9 (1943), p. 330.

9 A. W. Küchler, "The Relation Between Classifying and Mapping Vegetation," Ecology, Vol. 32 (1951), p. 281.

# IV. THE HOLDRIDGE MODEL

In 1947, Leslie R. Holdridge presented a system whereby world "plant formations" now designated "life zones" might be determined from climatic data. Based upon three parameters: temperature; precipitation; and potential evapotranspiration, the Holdridge diagram for classification (Fig. 1) differentiates the vegetation of terrestrial areas of the earth into approximately 120 broad environmental divisions. This section will discuss: 1) the theory and application of the Holdridge model; 2) how it compares with other classification schemes; and 3) previous tests of the system.

## A. Theory and Application

The fundamental assumption underlying the Holdridge model has been addressed succinctly by Tosi:

> The basic premise of the Holdridge theory is that among such sessile organisms as the land plants, each individual species-population has evolved (*i.e.*, has become specialized through selective adaptations) to successfully compete and survive as a member of the natural community within only a limited sector of the earth's broad climatic spectrum.[10]

From this supposition, Holdridge has proposed that the undisturbed natural vegetation on the earth's land surface precisely reflects prevailing environmental conditions and that climatic parameters,

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10 J. A. Tosi, Jr., "Climatic Control of Terrestrial Ecosystems: A Report on the Holdridge Model," *Economic Geography*, Vol. 40 (1964), p. 174.

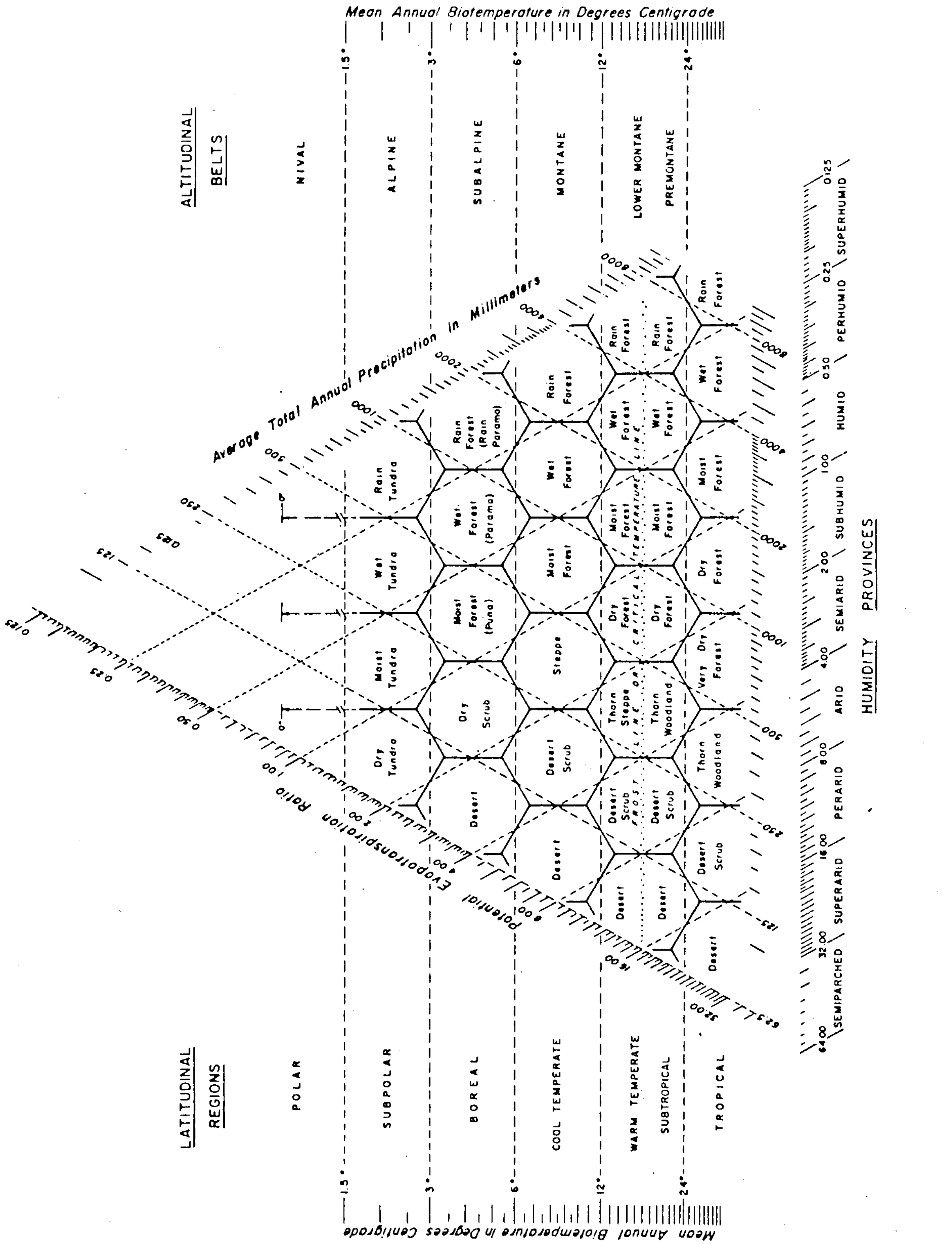


FIGURE 1: Diagram for the Classification of World Life Zones.

Source: Holdridge, op. cit., footnote 12, p. 16.

therefore, may be adopted to predict broad vegetation groupings.

1. Life Zone Concept

The Holdridge model (Fig. 1) is structured to divide the earth into ecologically equivalent units termed life zones according to temperature, precipitation, and potential evapotranspiration values. Holdridge defines a life zone as "a uniformly weighted division of the earth's climate which supports a distinct set of plant associations."[11] The life zones are only the first order, broad units of classification. The second order divisions, called plant associations, are defined by such factors as atmospheric conditions, soils, and topography. The life zone, then, may be thought of as "a group of associations related through the effects of...three major climatic factors; heat; precipitation; and moisture."[12]

2. The Life Zone Chart

The life zone chart shown in Figure 1 is a logarithmically based representation of the earth's life zones. Guidelines complying with experimentally determined values of heat, precipitation, and moisture as related to natural vegetation demark a set of triangles within which hexagonal units have been placed. Each hexagon represents the climatic limits of a particular life zone. The areas of intersection at the apices of the triangles describe life zones which are transitional in character. The diagram also

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11 L. R. Holdridge, "The Determination of Atmospheric Water Movements," Ecology Vol. 43 (1962), p. 2.

12 L. R. Holdridge, Life Zone Ecology, (San Jose, Costa Rica, Tropical Science Center, 1967), p. 15.

conveys both the latitudinal and altitudinal dimensions of the life zones. Seven latitudinal regions, from tropical to polar, are depicted on the left hand side of Figure 1. The altitudinal belts are indicated on the right hand side of the chart. The greatest number of altitudinal belts (six) are found in the tropical latitudinal region with the number of belts decreasing by one for each latitudinal region departure towards the polar realm. Thus one may find six altitudinal belts in a tropical region, five in a subtropical region, four in a warm temperate region, *et cetera*. A humidity province for each life zone, ranging from semiparched to saturated, is also indicated on the bottom portion of the diagram.

3. Determining Life Zones

Mean annual precipitation and mean annual biotemperature are the two climatic variables normally used to ascertain the life zone of a given point on the earth's surface.[13] The mean annual precipitation value employed in the Holdridge system is "the mean annual total of water in millimeters which falls from the atmosphere either as rain, snow, hail or sleet."[14] The mean annual precipitation scale is found on the left hand side and the base of the equilateral triangle comprising the chart (Fig. 1). The values shown increase logarithmically from 62.5 mm. yr.$^{-1}$ to 10,000 mm. yr.$^{-1}$.

The second climatic variable used to define life zones is

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13 Values of potential evapotranspiration may be used, but generally are not easily obtained.

14 Holdridge, *op. cit.*, footnote 12, p. 26.

mean annual biotemperature. This parameter, which relates plant growth processes to temperature, is simply a modification of mean annual air temperature obtained by substituting zero for values less than 0°C. or greater than 30°C. The mean annual biotemperature scales are shown increasing logarithmically from 1.5°C. to 32°C. on either side of Figure 1. The point where a given set of mean annual biotemperature and precipitation values intersect on the chart (Fig. 1) indicates the climatic limits of a particular life zone.

The latitudinal and altitudinal dimensions of the life zones are determined by a non-climatic variable, elevation. The station elevation expressed in meters above sea level aids in deciding whether a site belongs to a basal latitudinal region or one of the altitudinal belts. Either of two methods may accomplish this. The first utilizes a graph as shown by Figure 2.* The intersection of a station's mean annual biotemperature and elevation is plotted on the graph. If the point lies within a shaded area, the station is in a basal belt position and its latitudinal region name is given directly below the point. If, however, the point falls into an unshaded portion of the chart the station is in an altitudinal belt. The correct name for the altitudinal belt is given within the particular parallelogram that the point lies and the latitudinal region is again found directly below. In the other method of finding latitudinal and altitudinal ranges, an approximate value of 6°C. for each 1000 meters of elevation is used to calculate a hypothetical sea level biotemperature for the station. This

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* Note: Elevation figures are given on the right hand side while biotemperature values are shown running diagonally upwards and to the right from the base of this chart.

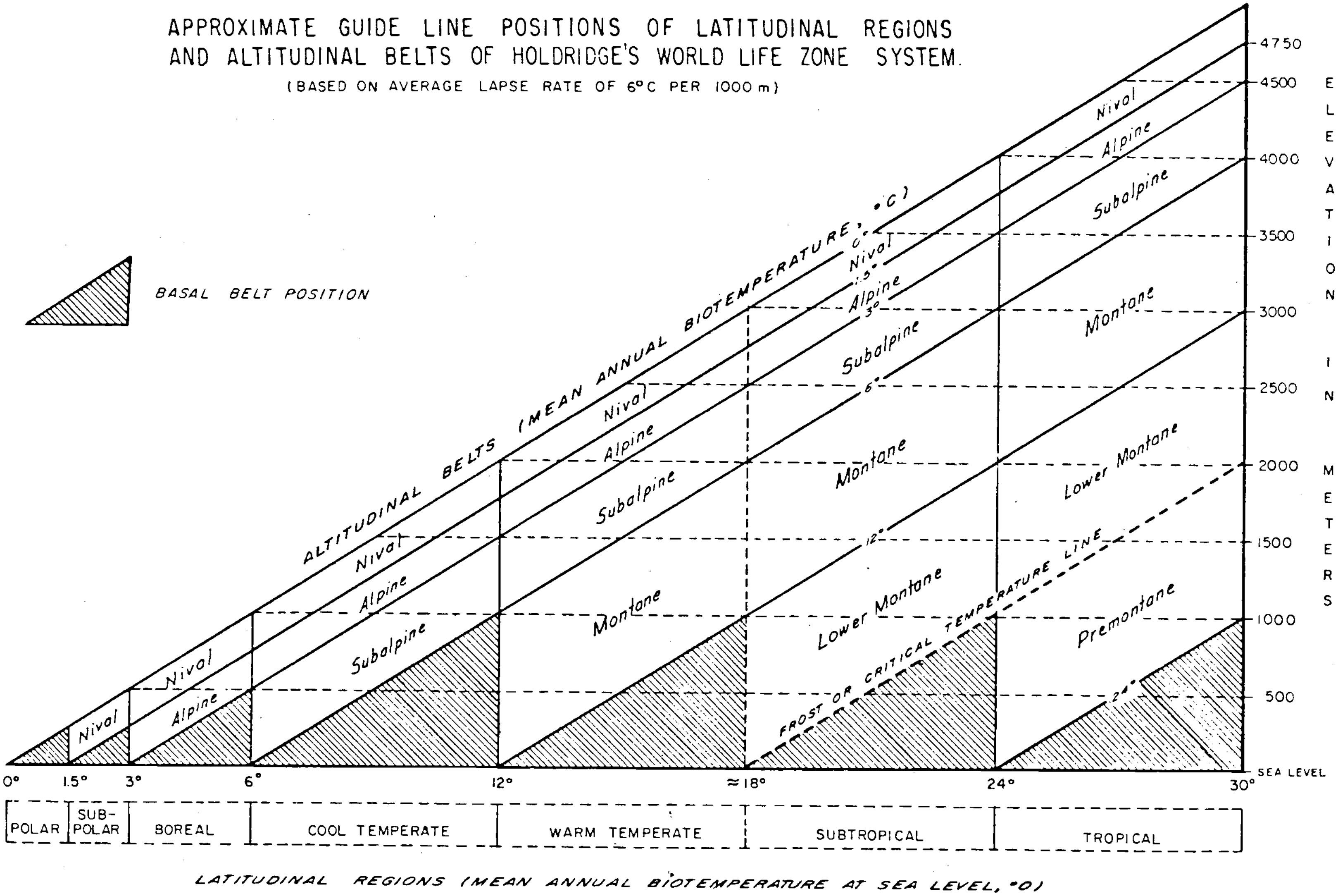


FIGURE 2: Approximate Guide Line Positions of Latitudinal Regions and Altitudinal Belts.

Source: Holdridge, *op. cit.*, footnote 12, p. 17.

hypothetical biotemperature can then be compared to the latitudinal regions and corresponding biotemperatures on Figure 1 to determine the basal latitudinal region. The altitudinal belt, if one exists for a given station, will be found in the column labeled such directly to the right of the hexagon in which the point lies on Figure 1.

In order to determine the proper life zone for a given location, then, one has only to utilize the mean temperature and precipitation values and the elevation of a station. The complete procedure may be illustrated by ascertaining the correct life zone for Bend, Oregon. The following data, based on a thirty year mean, were taken from the U.S. Weather Bureau publication Climatography of the U.S. No. 86-31 and given metric equivalence:

Station elevation........................................1098 m.
Mean annual precipitation................................305.8 mm.
Mean monthly temperatures................................

| J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|
| -1.0 | 1.1 | 3.5 | 7.0 | 10.4 | 13.6 | 17.6 | 16.8 | 13.5 | 8.8 | 3.6 | 0.7°C. |

First, giving zero values to those mean monthly temperatures outside the range 0°C. to 30°C., and then averaging them for the year one obtains a mean annual biotemperature:

$$t_{bio} = t_c \ / \ 12 = 0 + 1.1 + \ldots + 0.7 \ / \ 12 = 8.1^\circ C.$$

where,

$t_{bio}$ = mean annual biotemperature,

$t_c$ = corrected mean monthly temperatures.

Second, the intersection of this mean annual biotemperature value (8.1°C.) with the mean annual precipitation value (305.8 mm.) places Bend in the hexagon labeled "steppe" on Figure 1. Lastly, the latitudinal region and altitudinal belt are determined by intersecting the mean annual biotemperature value and the station's elevation on Figure 2. Bend is thus found to lie within the "warm temperate montane steppe" life zone.

If the alternative method is used to determine the latitudinal and altitudinal range of the life zone, the result is the same. Using the approximate rate of .006°C. m.$^{-1}$ the correction figure for Bend is:

$$.006^{\circ}C.\ m.^{-1}\ X\ 1098\ m. = 6.59^{\circ}C.$$

Adding this figure to Bend's mean annual biotemperature gives a hypothetical sea level biotemperature:

$$6.59^{\circ}C. + 8.1^{\circ}C. = 14.69^{\circ}C.$$

On Figure 1 this hypothetical biotemperature value corresponds to a "warm temperate" basal latitudinal region. The altitudinal belt is found directly to the right of the hexagon designated "steppe." Bend, therefore, is located in the "warm temperate montane steppe" life zone.

4. Mapping Life Zones

Mapping life zones from climatological data alone would be possible if meteorological stations were both numerous and regularly spaced throughout an area. This situation is not often encountered, however, hence other methods have been used to aid the mapping process. Field observations and topographic maps are the most common supplements employed.

B. Comparisons With Other Classification Schemes

Interpreted strictly, the Holdridge model must be considered an empirical classification of climates in that it employs observed climatic parameters as a basis. On the other hand, because the Holdridge system attempts to integrate vegetation and climate through the biotemperature concept it might well be thought of as an ecological approach to vegetation classification. Tosi has perhaps approached the best explanation as to the difference between the Holdridge model and other classifications:

> Holdridge's system...differs from other currently accepted classificatory schemes which are primarily descriptive, in that it is neither a classification of climate nor a classification of vegetation but is, rather, a classification of the relationship which exists between them.[15]

At any rate, the Holdridge classification of life zones has several properties which distinguish it from others. First of all, the climatic bases of the Holdridge scheme have been derived experimentally from comparative observations of climatic factors and natural vegetation. Generally preferable to the selection of arbitrary limits, as with the Köppen (1900) and early Thornthwaite (1931) systems, the Holdridge life zones are, therefore, in direct agreement with observed natural phenomena. A second special feature of the Holdridge model is its method of expressing the element of heat as related to vegetation. A measurement of the heat which is effective in plant growth, biotemperature, is utilized as a basic climatic parameter of the classification scheme. Finally, the logarithmic structure of

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15 Tosi, op. cit., footnote 10, p. 175.

the Holdridge model differs from other systems. The progression of the biotemperature and precipitation values logarithmically on Figure 1 establishes divisions of equal weight in accordance with Mitscherlich's principle of limiting factors.[16]

## C. Previous Tests of the Holdridge Model

The Holdridge classification has been applied extensively throughout the tropical and subtropical regions of Central and South America with over a dozen countries having been mapped by Holdridge, Tosi, and others. The results of these have been quite satisfactory, and the maps have proven to be useful tools for scientists working in these areas.

Fewer tests of the system have been conducted in the middle and high latitude portions of the world. Sawyer (1963) provided one of the first, by mapping the eastern and central parts of the United States. The results from this application proved adequate in all but mountainous areas. To determine whether or not this failure of the Holdridge system in elevated areas was due to an inadequacy of the model, Thompson (1966) applied Holdridge's methodology to a portion of the Colorado Rocky Mountains with the aid of isothermal and isohyetal maps. Life zone distributions indicated by the model were compared with Forest Service vegetation maps and the conclusion drawn was: "...the correspondence

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16 Mitscherlich has shown that when an element is a limiting factor in plant nutrition, additions of that element up to the amount that could be utilized must be increased in logarithmic progression to obtain a sequence of equal increases in yield. (See Holdridge, op. cit., footnote 12, p. 14).

seems good."[17] Another evaluation of the Holdridge model is that of Steila (1966). He mapped Holdridge life zones in the Mediterranean area and found them "compatible in all respects" with the vegetation formations of Shantz and Marbut.[18] Finally, a study by Thompson (1969) provided a test of the Holdridge system in high latitudes. This analysis discovered the model ineffective in predicting the decline of timberline from the interior of Alaska to the coast.

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17 P. T. Thompson, "A Test of the Holdridge Model in Midlatitude Mountains," The Professional Geographer, Vol. 18 (1966), p. 190.

18 D. Steila, "An Evaluation of the Thornthwaite and Holdridge Classifications as Applied to the Mediterranean Borderland," The Professional Geographer, Vol. 18 (1966), p. 359.

# V. AREA OF STUDY AND METHODOLOGY

## A. Area of Study

The chosen region of study, Oregon, displays a complex diversity of climate, topography, and vegetation, thereby presenting an excellent test of the theoretic and pragmatic merits of the Holdridge model. The state of Oregon is located in a midlatitude, west coast position where the complicated interaction of continental and marine air help produce its variegated climate. Furthermore, the intercepting and blocking effects of mountain masses on precipitation and temperature add to the contrasting climatic conditions of Oregon. Topographic relief features extend from near sea level river valleys to mountain peaks in excess of 3000 meters in elevation. Lastly, the diverse vegetation patterns of Oregon encompass several types from dense forest to sparse shrub.

## B. Methodology

This portion of the presentation will detail the methods employed in delineating the life zone distribution map of Oregon from climatic data through the application of the Holdridge model.

### 1. Collection of Data

A total of 165 meteorological stations throughout the state of Oregon having both mean annual precipitation and mean monthly temperature data were chosen for this study. As indicated in Table 1, the greatest percentage of the total stations had means calculated over relatively long time periods. Figure 3 depicts the spatial distribution of the data stations and also indicates, by selected

TABLE 1.--STATION MEAN RANGES: TOTALS AND PERCENTAGES

| No. of years means based on | No. of stations | % of total stations |
|---|---|---|
| 30 | 58 | 35 |
| 10 - 29 | 64 | 39 |
| 5 - 9 | 39 | 24 |
| 5 | 4 | 2 |

ranges, the time period over which the station means were based. Unfortunately, as illustrated by the map (Fig. 3), the regions where station data are sparse (i.e., in mountainous areas and the southeastern portion of Oregon) also contain a number of stations with means based on short records. Nonetheless, no particularly anomalous positions of life zone categories were observed so that the data means seem to have been quite adequate.

Two U.S. Weather Bureau publications were used as sources for the temperature, rainfall, and elevation data. First, summarized means for 128 stations, based on five to thirty year periods between 1931 and 1960, were obtained from Climatography of the United States No. 86-31. Second, means were computed for an additional thirty-seven stations from data recorded since 1965 using the publication Climatological Data: Oregon. The time period of the later calculated means ranged from two to six years.

2. Determining Life Zone Categories

Transformation of the data to metric equivalence was the first step to ascertaining the life zone classification for each of the selected meteorological stations. Next, conversions of the mean monthly temperatures to mean annual biotemperatures were performed as

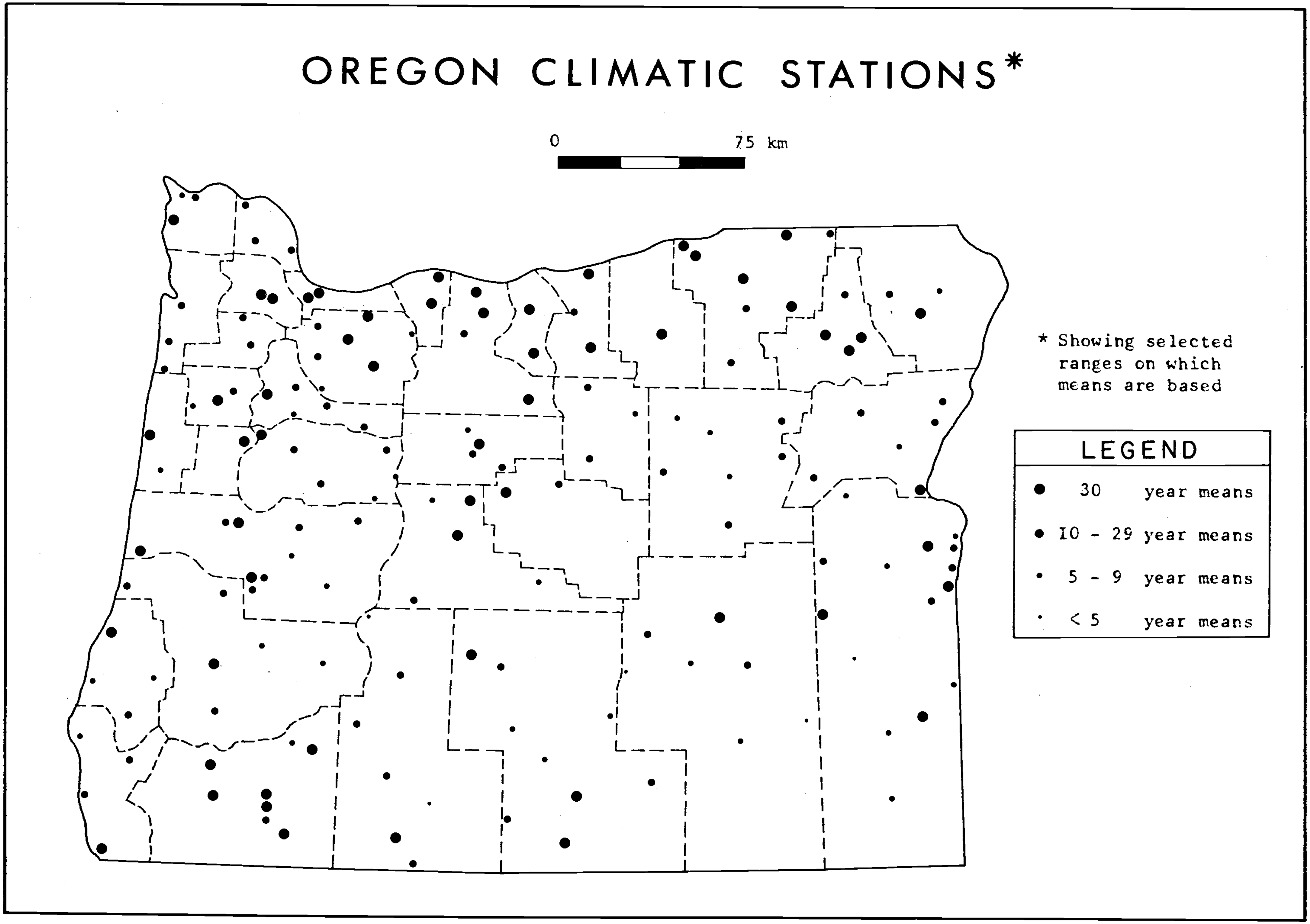


FIGURE 3: Oregon Climatic Stations.

previously outlined. These along with the mean annual precipitation and station elevation values provided all of the necessary parameters for determining the life zone categories.

Mean annual biotemperature and mean annual precipitation values were plotted on the Holdridge life zone diagram to discern the climatic limits (i.e., whether moist forest, steppe, et cetera) of each station. The latitudinal regions and altitudinal belts for the stations were determined by intersecting mean annual biotemperature values and station elevations on the "guide line" chart shown by Figure 2.

3. Compilation of the Life Zone Map

A map produced by Raisz, "Landforms of the Northwestern States," (1941) was adopted as a base map for the final compilation. Each station was coded on the Raisz map according to its life zone grouping and division boundaries were drawn. The Raisz map was a particularly useful aid in separating basal, montane, and subalpine regions. In addition, information concerning the transitional character of some stations proved meaningful in interpolating boundary lines. The final map (Fig. 4) was drafted at the scale of 1:1,300,000 and photographically reduced for presentation.

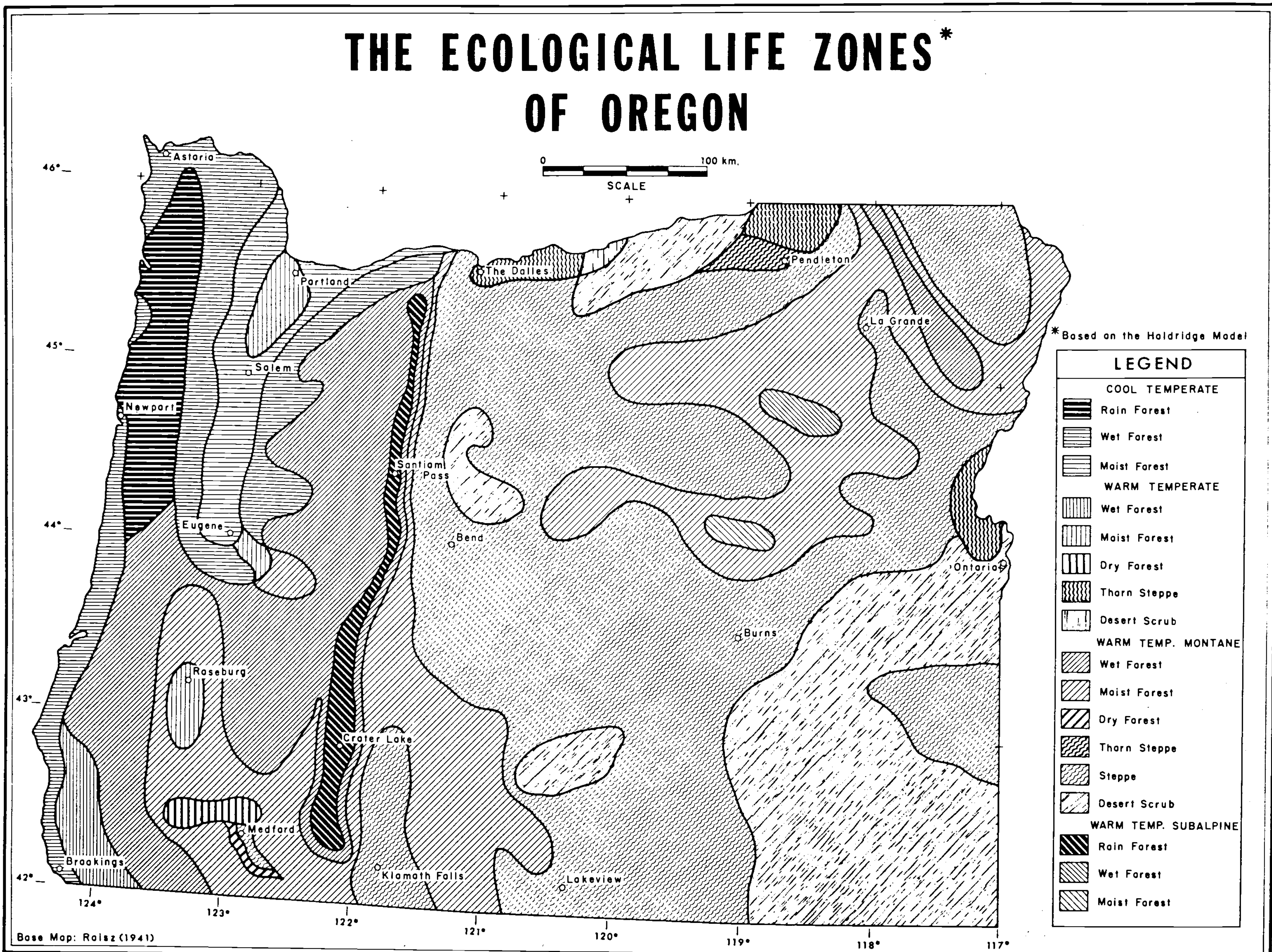


FIGURE 4: The Ecological Life Zones of Oregon.

## VI. EVALUATION OF THE LIFE ZONE MAP

Any map which purports to display the distribution of a specific phenomenon should, to be sure, compare reasonably well with other maps on which the same subject is illustrated. The question arises, however, particularly with the Holdridge life zone map presented here: upon which map(s) can a reasonable assessment be based? Fosberg warns against the use of circular reasoning when conducting map comparisons:

> If a vegetation map that is really a map of an ecosystem including climate as one of its bases is compared with a climatic map there will certainly be a correlation, but it may be a false one.[19]

Thus, the life zone map in this presentation should not be tested by evaluating it against climatic maps, but through comparisons of the broad vegetation units it defines with maps based on actual or potential vegetation distributions.

### A. Visual Comparisons

A number of maps depicting the actual or potential natural vegetation realms of Oregon are found in the literature. Two will be considered for comparative purposes: 1) Küchler's map of potential natural vegetation of the United States;[20] and 2) a map of the natural vegetation of Oregon by Franklin and Dyrness.[21] The reader is

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19 Fosberg, op. cit., footnote 4, p. 75.

20 A. W. Küchler, Potential Natural Vegetation of the Conterminous United States, (New York: American Geographical Society, 1964), map supplement.

21 J. F. Franklin and C. T. Dyrness, "Natural Vegetation of Oregon and Washington," USDA Forest Service General Technical Report PNW--8, (1973), p. 44-45.

referred to either one of these publications for the following discussion.

Visually comparing the life zone distribution map of Oregon (Fig. 4) with the Küchler or Franklin and Dyrness maps, broad congruities may be noted. First of all, a general vegetation zonation pattern follows the mountain and valley regions from the Pacific Ocean to the east side of the Cascade Range on each map. Secondly, the steppe and desert scrub regions differentiated on the Holdridge life zone map in eastern Oregon equate reasonably well with the same type of categories of the other two maps. Finally, vegetation associated with the mountainous areas of northeastern Oregon on the vegetation maps is shown on the life zone map similarly as "warm temperate montane and subalpine" forests.

Contrary to these agreements, however, some areas on the life zone map fail to correlate with actual vegetation patterns. Vertical zonation on Steens Mountain of southeastern Oregon, for example, is not depicted. Likewise, the alpine regions of the Cascade Range are missing on the life zone map. These discongruities seem, though, to be related to insufficient climatological data rather than an inherent weakness in the Holdridge model itself.

## B. Further Evaluations

Other evaluations, independent of comparative analyses, may also be made concerning the validity of the life zone map. It is significant to note, for instance, that stations in close proximity reveal no contrasting relationships (*e.g.*, rain forest and steppe in near juxtaposition). Moreover, rational transitions related to topography or geographic position occur in most situations. One possible anomaly may, however, be associated with the use of climatic data obtained within urban heat islands. The city of Portland, specifically, may be cited. Meteorological recordings from within the city place Portland in a warm temperate moist forest life zone while the Portland airport is discovered to be a cool temperate moist forest from its data. Perhaps the slight difference in heat within the city is sufficient to give it a higher biotemperature and consequently a warmer latitudinal classification than might be expected.

# VII. RECOMMENDATIONS FOR OTHER STUDIES

A variety of suggestions for further applications and testing of the Holdridge model have evolved from this study. These include: 1) detailing additional divisions of the life zone map; 2) other means of life zone map compilation; and 3) techniques for testing the validity of the Holdridge model and the life zone map of Oregon.

## A. Additional Divisions

In that the life zone categories are only the first order units defined by the Holdridge classification scheme, a logical progression from this presentation is to define the second order "plant associations" for areas of particular concern. For example, important watershed, recreation, or agricultural areas might be examined in detail with plant association information characterizing local edaphic, atmospheric, or hydric conditions. Additionally, significant knowledge concerning runoff and potential evapotranspiration at data points may also be obtained from equations and nomograms developed by Holdridge from the basic model.[22]

## B. Other Compilation Methods

If a larger scale map than that produced in this presentation is desired, the employment of topographic maps for interpolating life zone boundary lines might yield information with further de-

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22 These are discussed in: Holdridge, op. cit., footnote 11, p. 1-9.

tails. It must be remembered, however, that sets of contour lines themselves do not always demarcate climatic or vegetation zones. Hence, at large scales field checking is certain to become necessary. Ewel and Whitmore employed field reconnaissance in compiling a Holdridge life zone map of Puerto Rico.[23] Areas between stations with contrasting life zones were traversed and locations of changes or transitions in vegetation types noted. The methodology of Thompson (1966), where isothermal and isohyetal maps were used for supplemental data information in mountainous areas, may also prove helpful in detailing certain regions.

Another method for the compilation of a life zone map might be to utilize profiles. To begin, a number of transects would be drawn through as many climatic stations as possible on a planimetric map of the area of interest. The transects, then, would be plotted in profile and each station's life zone indicated. Lastly, interpolations would be conducted on the profiles using elevation data and then transferred back to the planimetric map for final detailing. This procedure would minimize the amount of climatic data required and aid the interpolation procedure where climatic data are wanting.

## C. Testing the Life Zone Map

Differences in exactly how categories are defined and interpreted complicate any attempt at comparisons of mapped distributions.

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23 J. J. Ewel and J. L. Whitmore, "The Ecological Life Zones of Puerto Rico and the U.S. Virgin Islands," USDA Forest Service Research Paper ITF--18, (Dec. 1973), p. 7.

This in particular is discovered when examining the correspondence between the life zone map of Oregon and maps showing actual vegetation distributions. Testing the life zone map for areal extent or boundary correlations, then, would probably be futile. A quantitative analysis of point data may, however, provide further insight into the validity of the Holdridge model and the life zone map of Oregon.

A conceivable evaluation might be to statistically examine the reliability of life zone categories in accurately describing the potential or actual vegetation at data points. First, a simplification could be made by considering only the vegetation type described in the life zone name (i.e., moist forest, steppe, and so on). Sample stations would then be drawn from a list of each of the life zone categories with the number in the sample varying by the total class size. The life zone classification of the sampled stations could be compared with qualitative vegetation descriptions from maps or the literature and a decision made as to whether the two are basically similar (e.g., can a station within an area where *Pseudotsuga menziesii* is the dominant species be considered to lie inside a moist forest classification?). Having performed this admittedly difficult task for each sampled station, statistical evaluations could then be made as to the dependability of the Holdridge model in predicting vegetation types from climatic data. If the number of similarities noted in each category were considered observed values (O) and the total number of sampled stations in each category designated expected values (E), chi-square ($x^2$) might be employed as the test statistic. The total expected frequency in each category should be at least five and the total number of stations should be at least twenty for the chi-square test to be valid.[24] The following example outlines the procedure of testing a hypothetical set of data with chi-square:

Data Set:

| Category | O | E |
|---|---|---|
| Rain Forest | 8 | 10 |
| Wet Forest | 10 | 12 |
| Moist Forest | 12 | 15 |
| Dry Forest | 4 | 5 |
| Steppe | 13 | 14 |
| Desert Scrub | 6 | 8 |

Null Hypothesis:
The life zone categories are not significantly different than actual or potential vegetation types.

Alternative Hypothesis:
The life zone categories are significantly different than actual or potential vegetation types.

Chosen Significance Level: 99%

Degrees of Freedom: No. of categories - 1 = 5

Critical Chi-Square Value: 15.09

Chi-Square Test:

$$x^2 = \frac{(O-E)^2}{E} = \frac{(8-10)^2}{10} + \frac{(10-12)^2}{12} + \ldots + \frac{(6-8)^2}{8}$$

$$= 2.1$$

Conclusion: Since $2.1 < 15.09$, we fail to reject the null hypothesis

24 J. P. Cole and C. A. M. King, Quantitative Geography (New York: John Wiley and Sons, Ltd., 1968), p. 135.

and conclude that at the 99% significance level the life zone categories are not significantly different than actual or potential vegetation types.

This suggested test would illustrate only how well the Holdridge model may be expected to predict vegetation types at data locations. Perhaps the best test of the model and the life zone map of this presentation will be their applicability in various practical problems related to ecological studies.

## VIII. SUMMARY AND CONCLUSIONS

An ecological life zone map of Oregon has been compiled by utilizing the Holdridge model. Visual comparisons between maps depicting actual vegetation distribution in the state and the life zone map have also been conducted. The similarities noted from this evaluation and the logical patterning of the life zone map demonstrates some merit in the Holdridge classification scheme. Further tests are recommended to determine how well the model predicts broad vegetation types. This study provides a basis from which these examinations and other applications of the Holdridge model might begin.

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