Vegetation-climate Relationships in the Eastern United States

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Abstract

Biotemperatures and normal annual precipitation values for the many meteorological stations in 8 of Braun's forest regions were plotted on the graphical base proposed by Holdridge. Climatic range figures, which clarify relationships among the forests, were drawn. Forests were also compared on the basis of means for each type of climatic data, emphasizing especially the potential evapotranspiration/precipitation ratio, an inverse measure of effective moisture.

The Holdridge model (3, 5, 7) of world bioclimatic formations or life zones is based on a triangular graph of biotemperature, annual precipitation and potential evapotranspiration/precipitation ratio (E/P), with each axis logarithmic on the base 2. The new application of the Holdridge concept reported herein requires only the skeleton graph, thus emphasizing the continuous gradients of climatic change rather than the subdivision into life zones and intervening ecotones, humidity provinces and other relatively fixed classificatory units which have proved useful for land description and mapping in tropical America (2, 4, 7, 8).

While working on the distribution map of the Holdridge life zones east of the 102 W. meridian in the United States (6), we computed biotemperature and normal annual precipitation values for 1400 Weather Bureau stations. These data, insofar as applicable to forest associations, were used in the present study. The oak-hickory type was omitted because its western boundary is not clearly determinable. Although any general vegetation map of the eastern United States might have been used to illustrate the method, that by Braun (1) was selected. The weather stations were classified according to their location within 8 of the major forest regions recognized by Braun. Even stations which fell on regional boundaries were used, but their borderline status was recorded.

The station data from the different regions were plotted using distinctive symbols, with the borderline stations so indicated, upon a large graph having the three axes as proposed by Holdridge. To facilitate analysis of results as exhibited by patterns of colored symbols on this elaborate working graph, the latter was used as the basis for two graphs (Figs. 1 and 2) presenting climatic ranges from distinct approaches. In Figure 1, the figures for full range of climate for each type of forest were drawn to include essentially all stations

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located within the given region. Since even the scattered, peripheral stations were included, the figures overlapped considerably. Despite this, Figure 1 shows that the climatically central forest association is Braun's mixed mesophytic, and that most others diverge from this in different directions on the graph. However, this does not hold for oak-chestnut which is very similar to mixed mesophytic climatically, indicating that the former can hardly be a climatic climax, but was probably segregated from the mother type by factors more related to substrate, or other factors not plotted.

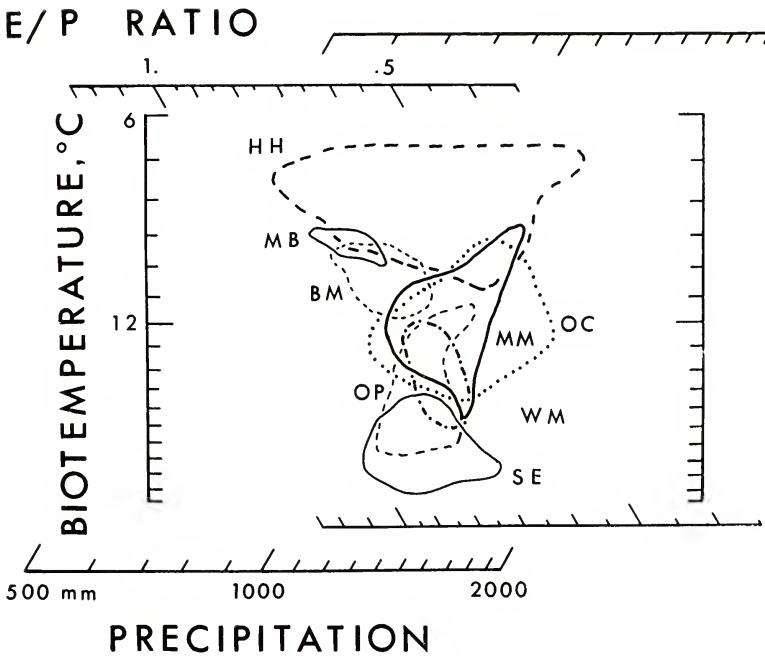

FIGURE 1. *Three-axis graph from plotting all stations to show climatic amplitudes of the Forest Regions. HH, Hemlock-Hardwoods; MB, Maple-Basswood; BM, Beech-Maple; MM, Mixed Mesophytic; OC, Oak-Chestnut; OP, Oak-Pine; WM, Western Mesophytic; and SE, Southeastern Evergreen.*

Little of the graph area within the oak-pine figure is not shared with some other figure. This indicates that oak-pine also is not a climatic association but is closely related to several other forests transitionally or serally. Both climatically and geographically, oak-pine is transitional between southeastern evergreen and one of the hardwood forests to the north. The hemlock-hardwoods type covers a very broad climatic range from its drier portions in the Lake States (left side) to its moister ones in New England, and relatively little of its climatic range is overlapped by any other deciduous forest. This suggests that traditional ecological theory should accord it climatic climax, rather than mere transitional, status. Beech-maple occupies a relatively compact, narrow range climatic type which is distinctive for this forest, so that beech-maple clearly appears to be a climatic association. At its cooler and drier end is maple-basswood which shares two-thirds of its small graph area with hemlock-hardwoods and beech-maple.

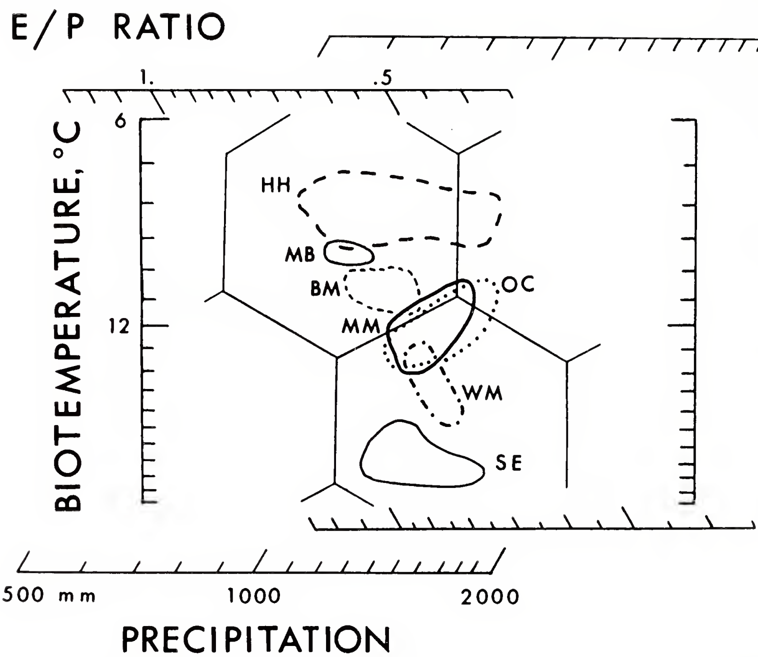

FIGURE 2. *Three-axis graph from plotting the most concentrated 4/5 of the weather station data in each Forest Region, to show the most typical climatic conditions in each Region. (See Figure 1 legend for meaning of region symbols. The upper left hexagon delimits the Cool Temperature Moist Forest of Holdridge, the upper right shows the Cool Temperate Wet Forest, and the lower center hexagon depicts the Warm Temperate Moist Forest. The forest climate figures fall largely within the two hexagons representing the Moist Province.)*

Figure 2 resulted from encircling the major concentration of plotted forest symbols, disregarding their peripheral scattering in order to bring out more definitively the climate that characterizes the particular forest. Approximately one-fifth of all dots were excluded from the figures. The transitional oak-pine type was omitted because no part of its diffuse dot pattern showed special concentration.

In order to compare the units of Holdridge's model with our stricter (Fig. 2) rather than looser (Fig. 1) interpretation of climatic relations, the lines marking his life zone hexagons have been included in Figure 2. The hemlock-hardwoods, maple-basswood, and beech-maple figures are there confined entirely to Holdridge's Cool Temperate Region. The southeastern evergreen, oak-pine, and western mesophytic figures occur exclusively in Holdridge's Warm Temperate

Region, as in Figure 1 also. Only the two central figures, mixed mesophytic and oak-chestnut, occur in both Warm and Cool Temperate but they cross into Cool Temperate to a slight extent only.

The maple-basswood, beech-maple, western mesophytic and southeastern evergreen figures are confined to Holdridge's Humid Province, which supports moist forests rather than the dry or wet forests of adjacent humidity provinces. The figures for hemlock-hardwoods, mixed mesophytic and oak-chestnut cross over to some degree from Holdridge's Moist Forest hexagons toward the Wet Forest, but only the hemlock-hardwoods (of New England) pushes into the Wet Forest substantially beyond the ecotone of the Holdridge chart (7).

The forest figures in Figure 2 show little overlapping, except for mixed mesophytic and oak-chestnut which appear even more similar than in Figure 1. Each of the other forest figures shows a rather distinctive principal climate for each forest. The usual climatic range for each forest may be described quantitatively from Figure 2. A simpler expression is its mean for each of the three climatic factors. These mean values, computed from the original station data, are presented in Table 1. The latter shows the mixed mesophytic forest as central in the list when the forests are ranked on a biotemperature or precipitation gradient, but quite near the moist end of the E/P gradient. The close similarity of mixed mesophytic and oak-chestnut is again evident; effective moisture averages very little more in the latter. When the 5 forests listed below the mixed mesophytic (Table 1) segregated from the latter, they apparently were becoming adapted to climates having lower effective moisture levels than the mixed mesophytic had or now has.

TABLE 1. *Mean climatic values for vegetation regions of the Eastern United States. (They are listed in* descending *order of effective moisture from top to bottom of the last column, which gives potential evapotranspiration/precipitation ratio, the inverse of effective moisture).*

	Biotemperature in °C	Precipitation in mm	E/P Ratio
Hemlock-Hardwoods	8.5	899	.556
Oak-Chestnut	12.0	1138	.622
Mixed Mesophytic	12.2	1117	.642
Beech-Maple	10.7	889	.706
Western Mesophytic	14.3	1186	.710
Maple-Basswood	9.5	739	.756
Oak-Pine	16.3	1196	.802
Southeastern Evergreen	18.9	1297	.859

The generally north-south geographic sequence of the forests (1) naturally corresponds well with the increasing biotemperature ranking. While the actual precipitation also tends to increase southward, the *effective* moisture, or inverse of the E/P ratio in Table 1, does not. The effective moisture is greatest in hemlock-hardwoods where there is only 899 mm mean precipitation, and is least in the southeastern evergreen type, which has the highest precipitation or 1297 mm. Still farther south, the higher biotemperature puts the southern tip of the Florida peninsula (6) into Holdridge's Tropical Dry Forest zone, despite the further increase in precipitation.

The average E/P ratio, since it integrates biotemperature, potential evapotranspiration and annual normal precipitation from many stations into a single value expressing effective moisture (insofar as climatically determined), is considered to be a highly significant numerical index of climate as it affects the distribution of vegetation.

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