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CORRELATION OF FOREST COMMUNITIES WITH ENVIRONMENT AND PHENOLOGY ON THE H. J. ANDREWS EXPERIMENTAL FOREST, OREGON[1]

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ABSTRACT

Air and soil temperature, leaf nutrient content, late summer plant moisture stress, and phenology were measured on 14 of the 23 forest communities recognized in the study area. The three vegetation zones identified differ considerably in a temperature index. Comparisons of an existing vegetation ordination with ordinations made using the results of this study showed that the x axis of the vegetation ordination represents a moisture axis. Although both temperature and nutrition correlate to some extent with the y axis of the ordination, it is not simply a response to any one or two factors studied. Yearday of selected phenological stages is well correlated with the temperature index used, but not with ordination axes.

The maximum predawn moisture stress and the calculated temperature index effectively separate the previously classified communities in the study area. The range of the environmental indexes measured in this area is very similar to that in the eastern Siskiyou Mountain forests.

INTRODUCTION

The Oregon intensive study site of the Coniferous Forest Biome is the H. J. Andrews Experimental Forest. A considerable diversity of forest communities is included in this 6000-ha watershed, which extends from 450 to 1600 m elevation (Dyrness et al. 1974). Available resources allow only a small part of this area to be studied, requiring results to be extrapolated to the unsampled portion of the watershed. To extrapolate results in describing the area, and in modeling the processes occurring there, some meaningful method of stratification must be employed. The plant community is being used as a primary unit of stratification, as vegetation has long been considered to represent an integration of the total environment (Billings 1952).

For a stratification system to serve the needs of workers in several fields, more information about the stratification units than simply their species composition is necessary. To increase the usefulness of the community stratification, several environmental variables and plant phenology were measured on stands representing the more common and contrasting plant communities. These measurements were intended to provide data for use by other investigators, as well as being of interest in examining vegetation-environment relationships.

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[1] This is contribution no. 64 from the Coniferous Forest Biome. 1974.

The forest vegetation of the H. J. Andrews area has been described and classified into 23 communities shown in Figure 1. These communities occur in three vegetation zones: The *Tsuga heterophylla* zone of lower elevations, the *Abies amabilis* zone of the higher elevations, and a transition zone in which both *T. heterophylla* and *A. amabilis* apparently will be dominants in climax vegetation (Dyrness et al. 1974). The relationship between these communities within zones has been further clarified by a two-dimensional ordination technique. Dyrness et al. (1974) suggest that the zones differ significantly in temperature, whereas intrazonal variation in vegetation results primarily from differences in plant moisture stress. This paper reports environmental indexes derived from the measurements of environment made, and the relationship of these indexes to community composition and phenology.

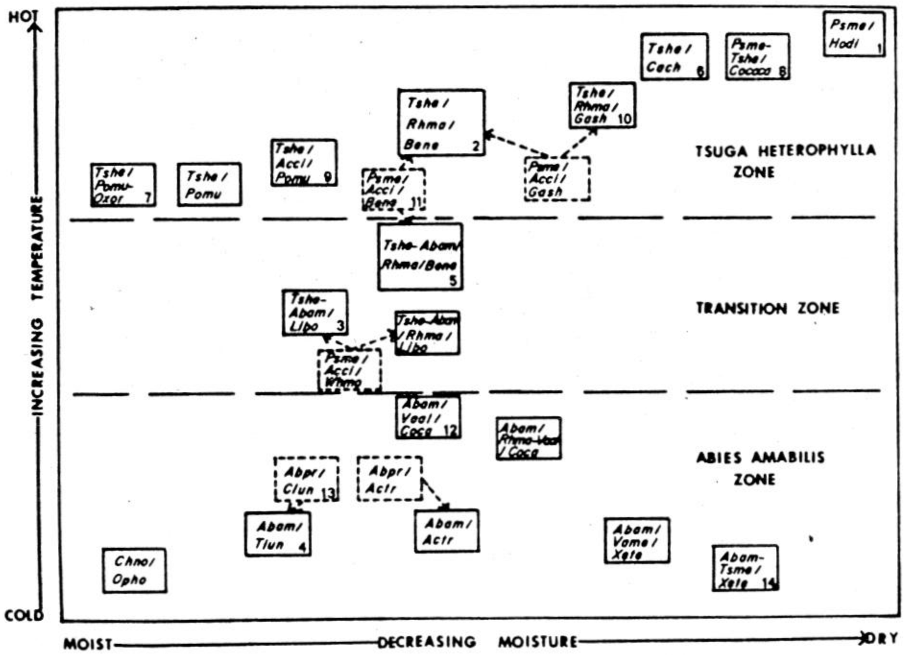

Figure 1. Hypothesized relationships between forest communities and environment on the H. J. Andrews Experimental Forest (after Dyrness et al. 1974). This figure is based on a vegetation ordination, somewhat modified by the intuition of the investigators. Communities enclosed with dashed borders are considered to be seral; the others, to be climax. Communities sampled in this study are identified by the reference stand number in the box. Abbreviations for communities are identified in Table 1.

STUDY AREAS

The more common and contrasting plant communities were chosen for study. In each community a reference stand (RS) was established. Each RS was chosen to exemplify the modal conditions of vegetation in the community it represented. Nineteen RS were established, but only 14 with the most complete data are used in this report (Table 1).

METHODS

Measurements made on the reference stands included predawn plant moisture stress, air and soil temperature, and foliar nutrient content. The phenology of selected species was observed.

Table 1. Forest community, elevation, slope, aspect and date of installation of each reference stand (RS).

RS	Forest community	Abbrev.	Elev. (m)	Aspect	Slope (deg)	Date
1	*Pseudotsuga menziesii/Holodiscus discolor*	Psme/Hodi	490	S40W	30	Apr 70
2	*Tsuga heterophylla/Rhododendron macrophyllum/Berberis nervosa*	Tshe/Rhma/Bene	490	N70W	21	May 70
3	*Tsuga heterophylla--Abies amabilis/Linnaea borealis*	Tshe/Abam/Libo	945	S85W	5	Apr 70
4	*Abies amabilis/Tiarella unifoliata*	Abam/Tiun	1310	N54W	20	Jun 70
5	*Tsuga heterophylla--Abies amabilis/Rhododendron macrophyllum/Berberis nervosa*	Tshe-Abam/Rhma/Bene	880		level	May 71
6	*Tsuga heterophylla/Castanopsis chrysophylla*	Tshe/Cach	610	S25W	30	Apr 71
7	*Tsuga heterophylla/Polystichum munitum--Oxalis oregana*	Tshe/Pomu/Oxor	460	N30W	29	May 71
8	*Pseudotsuga menziesii--Tsuga heterophylla/Corylus cornuta* var. *californica*	Psme-Tshe/Cococa	490	S85W	39	Apr 71
9	*Tsuga heterophylla/Acer circinatum/Polystichum munitum*	Tshe/Acci/Pomu	460	N50W	41	Apr 71
10	*Tsuga heterophylla/Rhododendron macrophyllum/Gaultheria shallon*	Tshe/Rhma/Gash	610		level	Apr 71
11	*Pseudotsuga menziesii/Acer circinatum/Berberis nervosa*	Psme/Acci/Bene	1010	S20W	11	May 71
12	*Abies amabilis/Vaccinium alaskaense/Cornus canadensis*	Abam/Vaal/Coca	1010	S40W	8	Jul 71
13	*Abies procera/Clintonia uniflora*	Abpr/Clun	1310	S20W	23	Aug 71
14	*Abies amabilis--Tsuga mertensiana/Xerophyllum tenax*	Abam-Tsme/Xete	1430	N33W	27	Aug 71

Plant moisture stress was measured on saplings under the stand in late summer of 1970-1972, using a pressure chamber (Scholander et al. 1965). At least four saplings, representing the major reproducing conifers, were sampled at each site on each date of measurement. Data presented here are the readings of the pressure chamber ("plant moisture stress" of Waring and Cleary 1967). This value represents the negative of the pressure potential of the xylem sap. For each year, the value used is the greatest average stress recorded on a single date at each site.

A thermograph was installed in each RS to continuously monitor air and soil temperature. Air temperature was measured at 1 m above the forest floor under an insulated A-frame shield. The soil temperature probe was buried 20 cm deep nearby. Averages were computed after the recorder charts were digitized. The mean daytime air and soil temperatures were used to compute a temperature-growth index (TGI). This index weights the temperatures by their relative effects upon growth of *Pseudotsuga menziesii* seedlings in a controlled environment and is summed over the "growing season" each year (Cleary and Waring 1969). This is intended to provide a representation of temperature that is more closely related to plant growth than are arithmetic averages alone. It is used as a uniform index to compare all the communities we studied; however its use over this wide range of conditions does not imply that other species, or even all populations of Douglas-fir, respond to temperature in a similar manner.

Foliage from several conifer saplings on selected RS was collected for chemical analysis in 1971 shortly after expansion of the current year's twigs. At this time of year nutritional stress in the plant should be at a maximum (Waring and Youngberg 1972). Samples were also collected in the fall. Nitrogen concentrations, presented here, were determined by a micro-Kjeldahl procedure by the Oregon State University Forestry Research Laboratory.

Both vegetative and regenerative phenological stages were observed in 1971 and 1972 for a variety of common and widespread species at all RS.

The community ordination based on vegetation alone (Dyrness et al. 1974) was compared with ordinations of the communities (as represented by RS) determined by plant moisture stress, temperature, foliar nutrient content, and phenology. Rank correlation methods were used to compare dates of phenological stage occurrence with x and y coordinates of the communities, and regression data of phenological stage on stand TGI also were computed.

RESULTS

Vegetation Zones and Temperature-Growth Index

The vegetation zones, as represented by the RS, had markedly different TGI. For the *Tsuga heterophylla* zone, all RS had TGI >73 in 1971 and >78 in 1972; the transition zone RS were 56 and 60 in 1971, and 67 and 70 in 1972, whereas the *Abies amabilis* zone RS had TGI <40 in 1971 and <49 in 1972.

Intrazonal Variation in Ordination Axes

Vegetation within the two warmer zones was used in a single two-dimensional ordination. Dyrness et al. (1974) had considered the x axis to represent variation in response to moisture stress, and the y axis to represent variation due to temperature. To check these interpretations, and axis positions of a given community in the *Tsuga heterophylla* and transition zones were compared with the moisture stress or TGI for the RS that represent it. Data from the *Abies amabilis* zone were insufficient to make such a comparison.

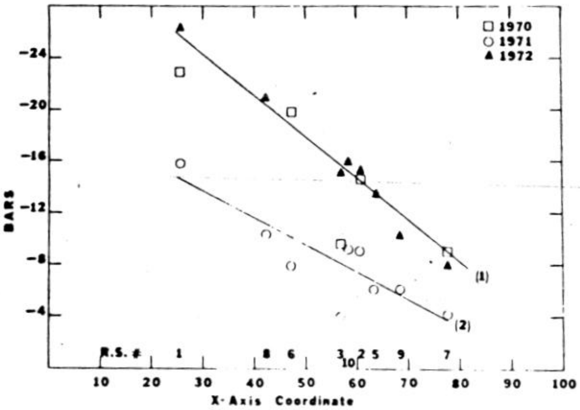

Figure 2. Relationship of maximum yearly predawn moisture stress to position of the community on the x-axis of the vegetation ordination of Dyrness et al. (1974). The community represented by each reference stand is listed in Table 1. Linear regressions: (1) 1970 + 1972: $y = -33.96 + 0.319x$, $r^2 = 0.95$; (2) 1971: $y = -20.00 + 0.207x$, $r^2 = 0.83$. (Data from RS 3 were excluded from the regression equations.)

The x-axis coordinate of the communities measured correlates well with the late summer predawn moisture stress as measured on the conifer saplings (Figure 2). The single major exception was RS 3, with less stress than predicted in 1970 and 1971. In 1972 RS 3 fit the regression, but only after a nearby selective cut increased the exposure of the stand to the west.

The *y* axis of the communities shows a rough relationship to TGI, but it breaks down at low *y* coordinates (Figure 3). Part of the stand variation in *y*-axis position could be related to nutritional status as well as to temperature. Reference stands 6 and 10 both have lower *y*-axis coordinates than would be expected from their TGI (Figure 3), but both are also lower in spring foliar nitrogen than the other stands (Figure 4). Reference stand 6 also has the lowest foliar nitrogen in fall sampling. Both *Tsuga heterophylla* and *Pseudotsuga menziesii* were sampled only at RS 6, where their foliar nitrogen contents were very similar. These stands also have lower nitrogen content in the upper soil horizons than other RS (R. B. Brown and R. B. Parsons pers. commun.). Unlike the *x* axis of the ordination, the *y* axis does not seem to be closely correlated with any single factor or combination of factors studied. This is not surprising. The *y* axis probably represents the effects of many environmental factors. Especially since the *x* axis is closely related to moisture stress, many environmental factors influencing plant distribution differently than moisture stress would be included in the *y* axis. The *y* axis probably includes, in addition, such variables as stand age and history.

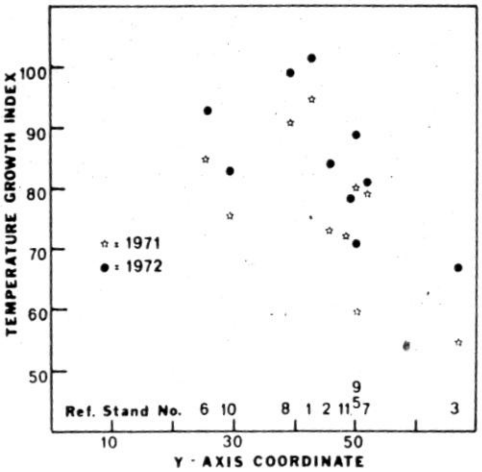

Figure 3. The relationship of TGI of a reference stand and the *y*-axis coordinate, in a vegetation ordination, of the community the stand represents.

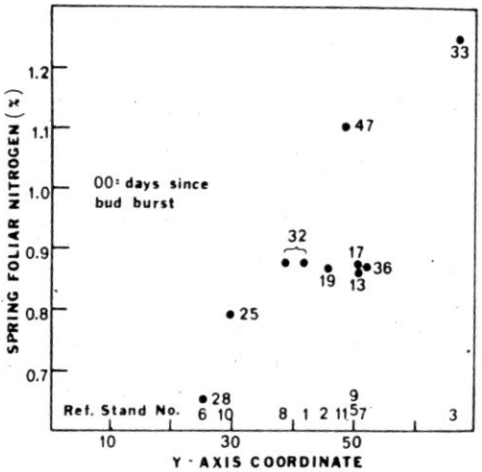

Figure 4. The relationship of foliar nitrogen content of year-old needles after budbreak in the spring (1971) to the *y*-axis coordinate of the community represented by each reference stand. Time since budbreak is listed with each point (days).

Phenology, Community Composition, and Environment

Although analyses of phenological data are not complete, those available do indicate that phenology may provide a useful alternative method of ordering communities. Dates of occurrence of selected phenological stages were observed for a number of species and their relationships to community ordination axes were examined. Ordering stands by different phenological stages gave similar results for several phenological stages of widespread species, except for *Tsuga heterophylla*. Budbreak of western hemlock occurred earlier in RS 6 and 10 than in RS 2 and 9, contrary to the other phenological stages studied. The ordination by phenological stages does not compare well with the vegetation ordination axes. Rank correlations of relative time of occurrence of a phenological stage at a particular RS with the position of the RS in the community ordination gave no good relationships with the x axis and only two with the y axis for the six phenological stages examined. Correlation of phenological stage occurrence with TGI at the various RS, however, was considered better than with the y-axis position of the communities. Phenological stages of common species showing a strong correlation of yearday of occurrence with TGI are listed in Table 2. All this indicates that phenology may provide an alternate means of determining temperature relationships of unstudied communities within the area, without actual measurements. Some phenological stages showed much poorer relationships with TGI, however, making calibration of each phenological stage necessary.

Table 2. Regression of yearday of phenophase (y) on TGI for the site for the given year (x).

Species	Phase[a]	Year	n	r^2	b
Tsuga heterophylla	01	1971	8	0.75	-0.80
		1972	9	0.95	-0.66
Abies amabilis	01	1972	5	0.86	-0.82
Linnaea borealis	01	1971	9	0.75	-1.29
		1972	13	0.88	-1.56
Chimaphila umbellata	01	1971	8	0.76	-0.94
		1972	11	0.91	-0.94
Viola sempervirens	12	1972	8	0.82	-1.35
Trillium ovatum	12	1972	8	0.91	-1.60

[a] Phase 01 = vegetative budbreak, phase 12 = occurrence of first flower; n = number of sites compared, b = regression coefficient, r^2 = coefficient of determination.

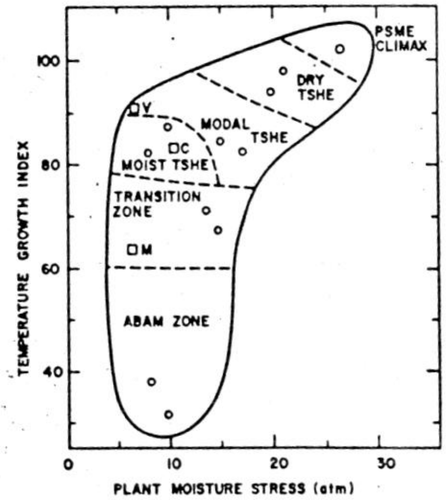

Figure 5. The position of reference stands in a two-dimensional environmental field. Temperature is represented by "temperature-growth index" computed by the method of Cleary and Waring (1969). Moisture is assessed as the late-summer predawn moisture stress on conifer saplings. Most data are for 1972. Psme = *Pseudotsuga menziesii*, Tshe = *Tsuga heterophylla*, Abam = *Abies amabilis*; "L" is discussed in the text.

The smaller negative regression coefficients for budbreak of the trees than of herbaceous species (Table 2) reflect greater uniformity in budbreak date with changing temperature conditions than for the smaller life forms examined. These herbaceous species thus should be more sensitive indicators of TGI than the trees studied.

Environmental Space Occupied by Communities

The variety of temperature and moisture conditions occupied by major forest communities of the H. J. Andrews area is represented in Figure 5. The moisture-temperature combinations present occupy only a part of the combinations possible, given the ranges of the two variables encountered. Reference stands 11, 12, and 13 have TGI for 1972 of 78, 49, and 37, respectively, but conclusive moisture stress data are lacking; RS 12 apparently is in the gap between RS 4 and 14 and RS 5 and 3, and RS 13 is very close to RS 4. Very warm stands with low moisture stress and moderate to cold stands with high moisture stress were not found. One site ("L" in Figure 5) on a rocky south slope on the Andrews Forest was measured with TGI = 63 and plant moisture stress = 26 (Zobel 1974).

This area had vegetation of a type not included in the classification of Dyrness et al. (1974), being a mixed stand of young *Pseudotsuga menziesii* and *Abies grandis*.

The relationship of the RS to the environmental indexes (Figure 5) is very similar to the hypothetical relationships shown in Figure 1. (Figure 1 was constructed before any of the environmental data reported here were available.) The only major exception is that there is not as much variation in moisture stress within the *Abies amabilis* zone as Dyrness et al. (1974) anticipated. The temperature-growth index separates the zones well, and the variation within the *Tsuga heterophylla* zone is mostly in response to moisture stress, as they predicted. That RS 2 and 10 are more different in vegetation (Figure 1) than in TGI and moisture stress (Figure 5) may be because of the apparently limited nitrogen availability on RS 10 (Figure 4).

Interestingly, the portion of the two-dimensional "environmental field" occupied by the RS in this study is very similar to that found for the eastern Siskiyou Mountains (Waring 1969), even allowing for differences caused by use of different years and definitions of "growing season" for TGI summation (Figure 6).

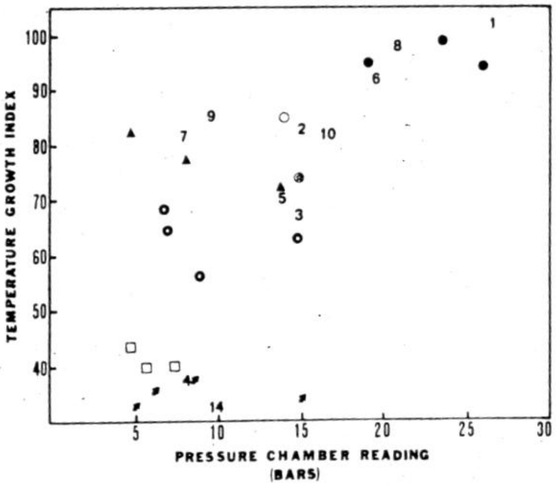

Figure 6. Comparison of temperature growth index and late season predawn plant moisture stress for forest communities in the central western Cascades and in the eastern Siskiyous (from Waring 1969). Numbers represent H. J. Andrews reference stands. Symbols represent eastern Siskiyou types: solid circles, black oak; open circle, yew; open circle and star, ponderosa pine; triangles, mixed conifers; solid circles and stars, white fir; open squares, Shasta fir; and arrows, mountain hemlock.

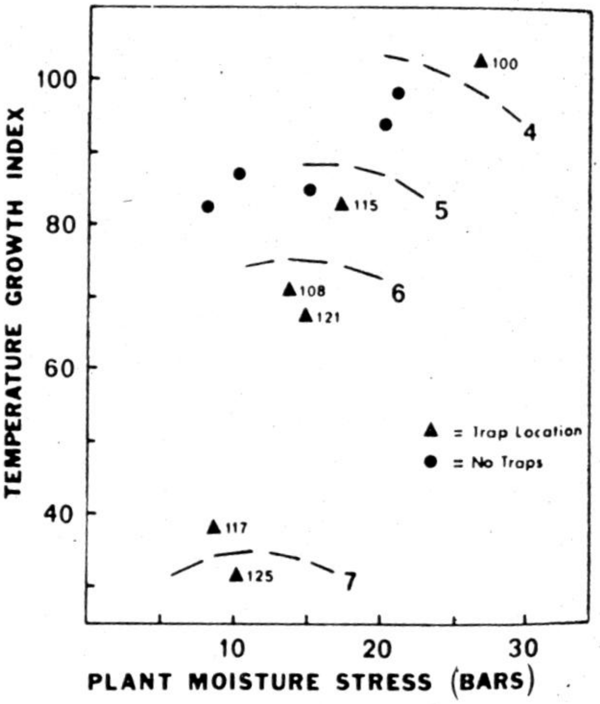

Figure 7. Numbers of individuals (small figures) and species (large figures) of shrews, voles, and mice on selected reference stands. A total of seven species were trapped. Data are total catch for five days, and are courtesy of R. A. Nussbaum.

Use of Reference Stand Data

Within the program of the Coniferous Forest Biome, the reference stands and the environmental and phenological data gathered there have been and will be used in many ways. Several types of studies have been done on or immediately adjacent to the reference stands: litterfall (Abee and Lavender 1972); litter decomposition, animal distribution and population density (Figure 7); soil properties (R. B. Brown and R. B. Parsons pers. commun.), vegetation composition; and understory biomass. Data on phenology are necessary inputs to modeling consumer and decomposition processes. Temperature is important for these models, as well as for hydrologic modeling. Primary production models depend on both temperature and phenology, as well as plant moisture stress (Sollins et al. 1974). The H. J. Andrews reference stand data will also be used as a part of the Biome environmental grid, which will attempt to determine Biomewide vegetation-environment relationships, as outlined by Waring et al. (1972).

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