INTERNAL REPORT 8

THE DEVELOPMENT OF A DISTRIBUTION—AND GROWTH—PREDICTION MODEL FOR THE ENVIRONMENTAL GRID

Richard H. Waring

Further development of an environmental grid for interpreting plant distribution and growth took place this past year as an attempt to solve problems associated with spatial diversity in ecosystems. Special emphasis was placed on developing more universal integrated indexes to environment, ones that might permit wide extrapolation throughout the range of at least one or two of the more widely distributed forest species.

The major environmental variables had been investigated in earlier field studies in southwestern Oregon. It was the task of this project to integrate these variables to more readily explain and predict plant distribution and growth. Major contributions to this effort arose from a conceptual model developed by Kenneth Reed in his thesis. Dr. Reed developed a mathematical model of daily transpiration for Douglas-fir, based upon (1) the nocturnal moisture stress, (2) air temperature, and (3) the atmospheric humidity. These variables were incorporated in a simulation program available in Fortran IV, which requires as input (1) seasonal change in predawn plant moisture stress, (2) knowledge of stomatal response in relation to predawn moisture stress, (3) humidity data (measured or predicted) from periodic sampling, and (4) temperature records from the environment under investigation. The program solves a differential equation for daily transpiration:

$$\frac{dT}{dt} = \frac{\Delta C}{R} = (\beta + \gamma t - \delta t^2)\ (\frac{1}{r_s} + \varepsilon) \qquad (1)$$

where $\underline{t}$ = transpiration in g cm^{-2} of leaf area
$\underline{\Delta C}$ = water vapor concentration deficit in g cm^{-3} (absolute humidity)
$\underline{R}$ = resistance of leaf to transpiration in sec cm^{-1}
$\underline{r_s}$ = stomatal resistance in sec cm^{-1}
$\underline{\varepsilon}$ = cuticular resistance in sec cm^{-1}
$\underline{t}$ = time, sec

By expressing the stomatal resistance as a function of time during the day, equation (1) can be solved analytically to provide an estimate of daily transpiration per unit leaf area. The potential transpiration, that which would occur if the stomatal resistance were at a constant minimum, can be calculated by solving equation (2):

$$\frac{dP\tau}{dt} = \frac{\Delta C}{4} \qquad (2)$$

where $\underline{P\tau}$ is the potential transpiration in g cm^{-2} and 4 is the minimum stomatal resistance in sec cm^{-1}. After obtaining τ and $P\tau$, a ratio of actual to potential transpiration may be calculated ($\overline{\Delta\tau}$). The two values, potential transpiration ($\underline{P\tau}$) and the ratio of actual to potential transpiration ($\Delta\tau$) were found to be most useful in interpreting the ability of forest plants to respond to atmospheric demands in concert with internal resistances resulting from decreasing soil water potential and subsequent stomatal closure. Here, τ, $\underline{P\tau}$ and $\Delta\tau$ were simulated for 14 of 25 stations in the Siskiyou Mountains of southern Oregon. For the first time, it was possible to evaluate different regions where previous vegetation analyses were not interpretable with regard to single indexes. Environments of the 14 study sites ranged from $\Delta\tau$ = 1.0 to 0.29, $P\tau$ = 21.4 to 7.5 g cm^{-2}, end of summer zylum water potential = 25.4 to 5.2 atm. The $\Delta\tau$ values approaching 1.0 were restricted to areas where soil water was not limiting, either through increased storage capacity of the soil or as a result of seepage water.

From the more than 600 species found in the area, 47 were selected to serve as keys for identifying environments because of their rather narrow environmental distributions or unique patterns of overlap with other species. A computer model was constructed using these species to estimate the following variables: (1) potential transpiration, (2) ratio of actual to potential transpiration, (3) temperature index based on an integrated evaluation of dry-matter accumulation during the period from bud swell to fall dormancy in Douglas-fir, (4) the maximum moisture stress reached near the end of the growing season, and (5) the presence or absence of extremely infertile soils. The distributional model was tested by predicting environments of other stations not originally incorporated in the model. Results were encouraging and further efforts using the data from the Andrews intensive site are envisioned.

Productivity in relation to various environmental variables was first investigated by means of a stepwise multiple regression. The independent variable was maximum height of dominant and codominant trees in steady-state ecosystems. The dependent variables were: temperature index ($\underline{TI}$), potential transpiration ($\underline{P\tau}$), ratio of actual to potential transpiration ($\Delta\tau$), and a soil fertility index. The regression model used was

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_6 X_6$$

where $\underline{X_1} = P\tau$
$\underline{X_2} = \Delta\tau$
$\underline{X_3} = \underline{TI}$
$\underline{X_4} = \overline{\Delta\tau^2}$
$\underline{X_5} = (\Delta\tau)(\underline{P\tau})$
$\underline{X_6} = (\Delta\tau)(\underline{TI})$

The $\Delta\tau$ was important alone and $\underline{P\tau}$ and $\underline{TI}$ were important as interactions with $\Delta\tau$. The regression equation accounted for 86% of the observed variance in tree height and had an $\underline{F}$ level of 64.9 with 6 and 62 degrees of freedom. This indicates that the variables $\underline{P\tau}$, $\Delta\tau$, and $\underline{TI}$ could be important integrative indexes of environment.

It is apparent that better estimates of productivity are desirable, particularly on ecosystems where tree density appears to be restricted to less than normal stocking. The relationship of growth to light has also been investigated but has not yet been incorporated into this particular model.

This project is officially terminated, but our programs are available to other investigators and are now being employed on data from stations on the Andrews site under a project directed by Dr. Zobel. The stomatal response model is also of some value in estimating transpiration in different areas of the Andrews Forest where the environment varies abruptly, as across the unit watersheds. The process studies of transpiration and photosynthesis being conducted by Scott and Walker at the University of Washington will likewise help to test some of the hypotheses developed in this preliminary effort.

Results of this research have been published as part of an IBP symposium at the Northwest Science meeting last spring. Dr. Reed's model will appear in *Ecology* and a summary of the work in southern Oregon will be submitted to *Ecological Monographs*.