AN INDEX FOR SOIL MOISTURE DRYING PATTERNS

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An index to approximate the drying patterns of various soil types was derived for budgeting soil moisture reserves. This index relates the ratio of actual and potential evapotranspiration to the relative plant available moisture content of soil. A wide range of curve shapes can be generated with this index by adjusting four control parameters. A simple technique for fitting the equation to observed drying patterns was also described. This technique replaces the previous method of using tables of coefficients to generate different drying curves. The technique will allow more efficient application of soil moisture budgeting to mapping, where estimates at many locations, on specific soil types are needed.

INTRODUCTION

Various empirical relationships have been suggested between the ratio of actual evaporation from a crop (AE) and potential evapotranspiration (PE) and soil moisture content (Baier 1969; Baier et al. 1972). It has also been shown that these relationships are controlled by soil properties, particularly texture (Baier 1968; Salter and Williams 1965). Several previously published soil moisture drying curves were used by Baier and Robertson (1966) in budgeting plant available soil moisture over the growing season. Their curves were controlled by tables of coefficients which were made independent of the plant available soil moisture capacity (ASMC) by expressing available soil moisture (ASM) as a fraction of ASMC. The drying curves have the general form of allowing evaporation to proceed at potential (AE = PE) until some critical value of ASM, where the AE:PE ratio starts to decrease as a function of ASM/ASMC. The decreasing portion of the curves have three typical shapes; concave upwards, linear and convex downwards. A separate table of coefficients had to be selected for each drying curve and only a few of these tables are currently available.

This paper describes a simple technique for indexing the so-called *z*-coefficients used in the Versatile Budget (Baier and Robertson 1966; Baier et al. 1972). This index characterizes the falling portion of the curves (AE < PE) as well as the potential case (AE = PE). This approach, which approximates the three curve shapes, was felt to be more useful than several independent functions that exactly fit each existing table of *z*-coefficients.

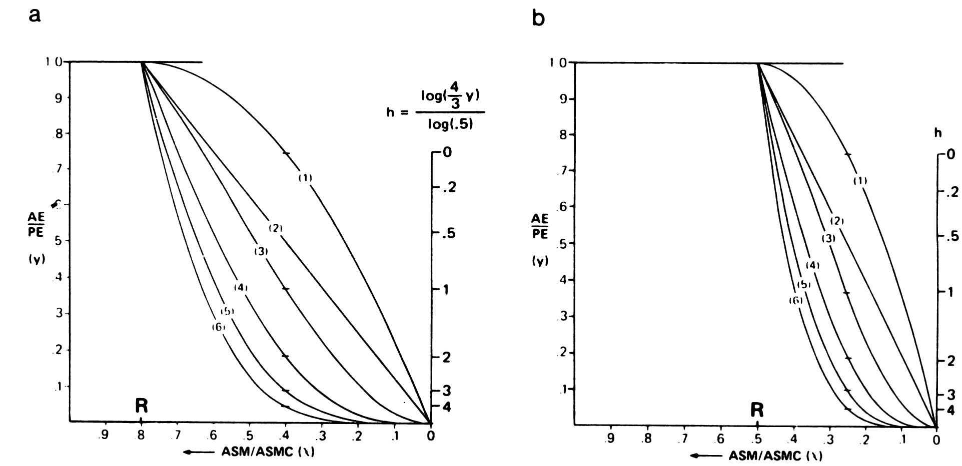

Figure 1. Drying curves derived from the proposed index for R = 0.8 (a) and R = 0.5 (b), and the relationship between h and Y at X = 0.5R.

INDEX DEVELOPMENT

Y denotes the AE:PE ratio, X is ASM/ASMC and both Y and X have a zero to one range. Z is a set of coefficients similar to those used by Baier at al. (1972) for which the index is intended. For simplicity, the effect of root distribution was ignored here. Thus,

$$Y = ZX \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

The two simplest cases of Z are for an evaporation rate at potential and an evaporation rate that decreases linearly to zero as soil moisture is decreased. In the first case, Z is given by $1/X$. The second case holds when X is less than a chosen constant R and Z is given by $1/R$. A third case was defined, which is a weighted average of the first two cases. Weighting factors that are functions of X and R were chosen so that when X is small the first term is made smaller and the second term is enlarged. The index now has the following unreduced form:

$$Z = \left(\frac{X}{R}\right)\left(\frac{1}{X}\right) + \left(\frac{R-X}{R}\right)\left(\frac{1}{R}\right) \quad \ldots\ldots\ldots \quad (2)$$

This index, when substituted in Eq. 1, gives a curve which is concave upwards (for $X < R$). By applying a multiplier (X/R) to Z, the Y curve was depressed downward. When this multiplier was squared, Eq. 1 was more deeply convexed while higher powers generate even more deeply convex drying curves.

By using exponential control parameters of zero or one to default the weighting factors to unity, and factorial control parameters of zero or one to default either of the additive terms to zero, the general expression for Z is:

$$Z = \left(\frac{X}{R}\right)^{hmn} \left(\frac{X}{R}\right)^{m} \frac{n}{X} + \left(\frac{R-X}{R}\right)^{n} \frac{m}{R} \quad \ldots (3)$$

The control parameters h, m and n can be used to reduce Eq. 3 to four different families of drying curves as well as to the potential case. Examples of these curves (numbered 1 to 6) are shown in Fig. 1 for two arbitrary values of R and five values of h (0 to 4). Table 1 gives the h, m and n combinations which generate each type of curve and the reduced form of Eq. 3 for each case. Note that Eq. 3 is the only form that allows all curve options to be used. Although Fig. 1 only illustrates whole number values of the curvature parameter (h) the index can be made more flexible by making h non-integer. By substituting Y/X for Z in Eq. 3, h can be defined as a logarithmic function of Y, X and R. The right axes of Fig. 1 show the unique relationship between h and Y, at $X = 0.5R$, for $0 < R < 1$ and can be used to estimate h when R and Y at $X = 0.5R$ are known. Thus, approximate curve fitting can easily be done using Eq. 3.

DISCUSSION

Fitting the index (Eq. 3) to a wide range of drying curves will allow characteristic drying patterns as well as water-holding capacities of specific soils to be used in computer soil moisture budgets. In one previous application (Earth Satelite Corp. 1976), where it was necessary at certain test sites to use a drying curve which was a compromise between two curves derived by Baier et al. (1972), such an index would have been useful. For mapping soil moisture reserves from climatic data, where estimates

TABLE I. COMBINATIONS OF CONTROL PARAMETERS USED IN EQUATION 3 TO GENERATE DIFFERENT DRYING CURVES AND THE FORM THAT EQUATION 3 IS REDUCED TO IN EACH CASE

Curves shape	m	n	h	Expression for Z	Curve number from Fig. 1a, b
Concave	1	1	0	$\frac{2R - X}{R^2}$	(1)
Convex	1	1	1	$\frac{2RX - X^2}{R^3}$	(3)
Deeply convexed	1	1	2,3 or 4	$\frac{2RX^h - X^{h+1}}{R^{h+2}}$	(4, 5 and 6)
Linear	1	0	0	$\frac{1}{X}$	(2)
Potential	0	1	0	$\frac{1}{R}$	
For $X < R$	0	1	—		

based on the soil texture at many locations are needed, this technique would permit some allowance for different drying patterns. This index can approximate those z-coefficients currently in use (Baier et al. 1972). It can be fitted exactly to the linear types by setting R to the appropriate value and n to zero, and very closely to the convex type by setting h to 4.

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