Water-Salinity-Production Functions

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ABSTRACT

WATER-salinity-production functions are mathematical expressions of the relationship between crop yield and the amount and salinity of applied water. If available, such relationships would be valuable aids to the study of water management practices throughout the arid West, where salinity can be a problem.

This paper presents a model for constructing water-salinity-production functions based on our current understanding of crop response to water, crop salt tolerance, and the leaching process. Available theory and data from which to derive water-salinity-production functions are assessed, and a numerical example is given.

INTRODUCTION

In arid agricultural areas, irrigation is often required to achieve economically viable rates of crop production. Knowledge of crop response to water is an important element in any assessment of irrigation practices. But since irrigation waters contain dissolved salts, salinity is a potential problem that must be considered simultaneously. Unless remedial action is taken, salts applied to the soil with the irrigation water will tend to accumulate in the soil, to the detriment of crop yields. Thus, knowledge of crop response to soil salinity is another important element in the evaluation of water management practices.

Much work has been done in each of these areas separately. An extensive body of literature documents attempts to quantify the response of many crops to water in the absence of salinity. Doorenbos and Kassam (1979) and Vaux and Pruitt (1983) provide good overviews and summaries of this literature. Similarly, much work has been done to quantify the response of crop yield to soil salinity in the absence of water stress (Maas and Hoffman, 1977; Maas, 1985). Data from each of these areas, when combined with a model relating saline water application to soil salinity, can be used to construct water-salinity-production functions that relate crop yield to the amount and salinity of applied water. Such functions should be valuable aids in the study of water management practices wherever salinity is a potential problem.

Production functions relate crop yield to the amount of agricultural resource(s) applied or made available to the crop throughout the growing season (Heady and Dillon, 1961). For example, water production functions relate crop yield to some measure of seasonal water use or application. Production functions are not intended to be definitive, mechanistic descriptions of how a crop responds to these agricultural inputs, but rather to summarize the results of the complex interactions by which the response is evidenced. As such, they have certain limitations, and cannot be employed indiscriminately. The review by Vaux and Pruitt (1983) gives an excellent discussion of factors that limit the validity and transferability of water production functions.

Given their proper use, production functions provide a very useful simplification and facilitate the evaluation of certain crop husbandry practices. Ayer and Hoyt (1981), for example, present water-nitrogen production functions for typical Arizona situations, and use them to assess the impact of various irrigation and pumping practices on crop yield and farm profit. The concept of water-production functions has even entered the popular literature (Larsen, 1978), accompanied by a discussion of seasonal water applications to maximize yield and profit. Water-salinity-production functions could be used to address similar questions when irrigation waters are saline.

This paper presents a relatively simple procedure for constructing water-salinity-production functions. Letey, et al. (1985) have validated a special case of this procedure against empirical data for tall fescue, supporting the validity of the concepts involved and the potential utility of the method. The focus of this paper is on the mathematical formulation and solution of a general steady state model for the construction of water-salinity-production functions.

THEORY

Yield Response to Non-Saline Water

As indicated by Doorenbos and Kassam (1979), considerable data suggest that crop yield (Y) is well correlated with the quantity of water evapotranspired by the crop during the growing season (E_t). Y can refer either to the total plant material (dry matter) produced, or only to the commercially valuable part of the plant (grain, fruit, lint, etc.). Most researchers have found yield, particularly dry matter, to be linearly related to evapotranspiration (Stewart and Hagan, 1973), though occasionally curvilinear relationships are found.

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Curvilinear relationships between Y and E_t have been presented for: cotton (Grimes et al., 1969); potatoes (Khanjani and Busch, 1982); wheat, barley, berseem and sugarcane (Gulati and Murti, 1979); citrus, sugarbeet (roots) and wheat (Doorenbos and Kassam, 1979). Maurer et al. (1979) show a non-linear relationship between corn yield (grain) and E_t for some schedules of deficit irrigation. Stewart and Hagan (1973) present further examples of non-linear Y-E_t relationships, and a good discussion of this phenomenon.

The function α will denote the general relationship between Y and E_t: $Y=\alpha(E_t)$, for $E_t \leqslant E_t^*$. E_t^* is the maximum E_t expected, with water not limiting, for the particular crop and locale of interest. (Throughout the following, Greek letters will be used to represent functions, with Roman letters denoting constants or variables.)

While yields may be related to E_t, the irrigator may not be able to respond to this relationship directly, since not all water made available to the plant goes to E_t. Of more direct interest to the irrigator would be a relationship between crop yield and some measure of applied water. Stewart and Hagan (1973) have recommended the variable "field water supply (F_{ws})" for this purpose. They define F_{ws} as the sum of effective rainfall (R) during the growing season, available soil water stored in the (future) rootzone at planting (A_p), and irrigation (I). Actually, A_p must come from either rainfall or irrigation, so $F_{ws}=(R+I)$, where both R and I are taken to include contributions from those sources to soil water available in the rootzone at the time of planting.

Many studies have been done relating Y to F_{ws}, since F_{ws} may be more directly influenced by the irrigator than E_t. Solomon (1983), for example, reviews over 140 such relationships, and presents typical water production functions for 37 different crops. Frequently it is the case that the relationship $Y=\beta(F_{ws})$ is non-linear, and in fact, for excess applications of water, yields may even decline due to a variety of mechanisms. With adequate drainage and fertility management, the rate of yield decline with excess F_{ws} may be slight. The typical situation is illustrated in Fig. 1. F_{ws} will never be less than E_t, because it is not possible for plant use to exceed supply. On the other hand, F_{ws} may exceed E_t, since water applied as F_{ws} may have fates other than E_t. Much of F_{ws} that does not go to E_t probably goes to deep percolation, though it may also go to surface runoff (Barrett and Skogerboe, 1980). Also, some unusual irrigation schedules might cause an excess of evaporation relative to the circumstances for which $Y=\alpha(E_t)$ was derived. If good irrigation management is practiced, eliminating non-E_t uses of water, F_{ws} may equal E_t, and the functions $\alpha(E_t)$ and $\beta(F_{ws})$ will coincide, at least for $E_t \leqslant E_t^*$.

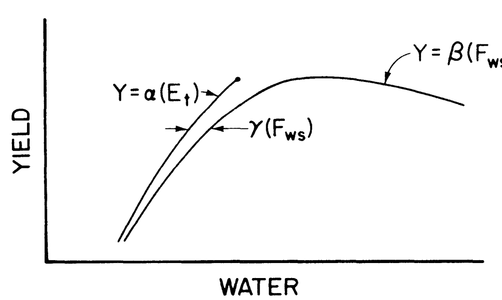

Fig. 1—Typical water production functions.

The function $\alpha(E_t)$ depends primarily on the crop and climate (Doorenbos and Kassam, 1979). As the above discussion suggests, however, $\beta(F_{ws})$ depends not only on crop and climate, but can be significantly impacted by the irrigation system and water management practices as well. A logical modeling sequence would be first to specify $\alpha(E_t)$ for the crop and climate of interest, then to specify the gap $\gamma(F_{ws})=(F_{ws}-E_t)$ between F_{ws} and E_t for the appropriate irrigation system and water management practices, and finally to construct $\beta(F_{ws})$ from these two pieces: $\beta(F_{ws})=\alpha(F_{ws}-\gamma(F_{ws}))$. Unfortunately, data on which to base the estimation of $\gamma(F_{ws})$ are scarce. A few studies were identified which made independent measurements of F_{ws} and E_t (Beese, et al., 1982; Grimes, et al., 1969; Gulati and Murty, 1979; Howell and Hiler, 1975; Stegman and Lemert, 1981; and Sewart and Hagan, 1973), and in each case, the data could be fitted reasonably well using a power function of F_{ws}: $\gamma(F_{ws})=k\cdot F_{ws}^r$, for $F_{ws} \leqslant F_{ws}^*$, where F_{ws}^* is the value of F_{ws} for which $\beta(F_{ws}^*)=\alpha(ET^*)$, and k and r are fitted parameters of the power function. Unfortunately, there is presently no basis for determining which values of k and r are appropriate for different irrigation systems and practices. This would seem to be a fruitful area for further research. Whenever possible, projects aimed at defining either $\alpha(E_t)$ or $\beta(F_{ws})$ should attempt to independently measure E_t and F_{ws}, and indicate the irrigation method and practice in their reports.

For the present effort, it is only necessary that two of the three functions α, β and γ be known. If γ is unknown, it may be estimated from $\gamma(F_{ws})=[F_{ws}-\alpha^{-1}(Y_w)]$, where $Y_w=\beta(F_{ws})$ is the yield corresponding to F_{ws} in the absence of salinity. This estimation will be valid so long as an inverse for α can be constructed, and the constraint $\gamma(F_{ws}) \geqslant 0$ is observed.

Soil Salinity

The amount and distribution of salt in the rootzone will depend on the amount and quality of the applied water, and on the pattern of water extraction for E_t. Assuming that no salts precipitate, dissolve, or are removed by the crop, Hoffman and van Genuchten (1983) derived steady state solutions for the average rootzone salinity as a function of the salinity of the applied water, the leaching fraction, and the water uptake function. If S_i is some measure of the salinity of the irrigation water, and it is assumed that rain water is non-saline, then time-averaged salinity of the field water supply (S_f) is given by: $S_f = S_i \cdot I/F_{ws}$. The leaching fraction (L) is defined as that fraction of the total water application that percolates through and below the rootzone. Let $\lambda(E_t,F_{ws})$ specify L as a function of E_t and F_{ws}: $L=\lambda(E_t,F_{ws})$. When irrigating with non-saline water, L will equal $[d_p \cdot \lambda(F_{ws})/F_{ws}]$, where d_p is the fraction of $\lambda(F_{ws})$ that goes to deep percolation. If, due to irrigation with saline water, the crop E_t is less than the value $\alpha^{-1}(Y_w)$, then the leaching fraction will be greater. Thus,

$$\lambda(E_t,F_{ws}) = [d_p \cdot \lambda(F_{ws}) + (\alpha^{-1}(Y_w)-E_t)]/F_{ws} \quad \ldots . [1]$$

Hoffman and van Genuchten (1983) considered three water uptake patterns: exponential and trapezoidal patterns, and a pattern where uptake from successively deeper quarters of the rootzone is proportioned as 40, 30, 20, and 10% of the total uptake. These uptake patterns

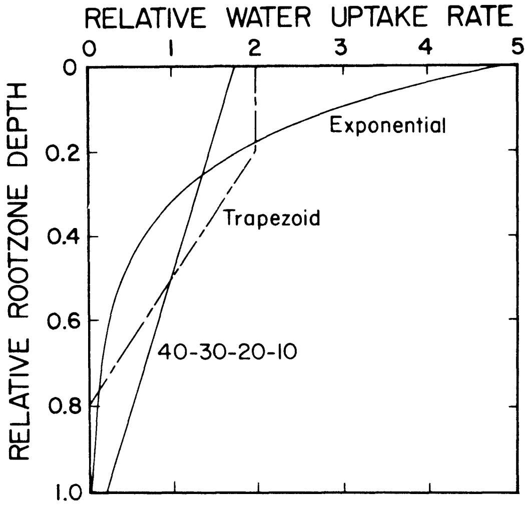

Fig. 2—Three water uptake patterns (after Hoffman and van Genuchten, 1983).

are illustrated in Fig. 2. They computed average rootzone salinity as both linear and uptake-weighted averages of salinity over depth. The models based on the linear averaging technique produced the best agreement between predicted and experimentally measured results, for all three uptake patterns. The model derived for the exponential uptake pattern provided the best fit with measured data. The linear average models of Hoffman and van Genuchten (1983) can be expressed as: $S_s = \delta(S_f, L) = (S_f/2) \cdot K(L)$, where S_s is the linearly averaged rootzone salinity, expressed as saturation extract salinity, dS/m, S_f is the salinity of the field water supply, dS/m, and K(L) is a function of the leaching fraction that depends on the water uptake pattern. For the exponential uptake pattern,

$$K(L) = (1/L) + (0.2/L)\left(\ln[L + (1-L)e^{-5}]\right) \quad [2a]$$

For the trapezoidal uptake pattern,

$$K(L) = (1/5L) - [1/(2-2L)]\ln(0.6+0.4L) + (1/a)\tan^{-1}(b)$$
$$a = [5L(1-L)/3]^{0.5}$$
$$b = [3(1-L)/5L]^{0.5} \quad [2b]$$

For the 40-30-20-10 uptake pattern,

$$K(L) = [10a/(1-L)]\,[\tan^{-1}(9a) - \tan^{-1}(a)]$$
$$a = [(1-L)/(81L-1)]^{0.5} \quad [2c]$$

Constraints on these expressions for K(L) are $0<L<1$ for equations [2a] and [2b], and $(1/81)<L<1$ for equation [2c].

Yield Response to Soil Salinity

The effect of soil salinity on crop yields can be expressed by a function that relates some measure of soil salinity to crop yield, relative to the yield expected under non-saline conditions (specific ion effects are ignored). Let S_s (salinity of the saturated soil extract, dS/m) be taken as the measure of soil salinity, y_s ($0 \leq y \leq 1$) be the relative yield due to rootzone salinity, and σ be the function that relates the two: $y_s = \sigma(S_s)$. The relative yield y_s may refer to either dry matter production, or to marketable yield. The responses of dry matter and marketable yield to salinity may differ. Maas and Hoffman (1977) have reviewed and summarized a large body of literature on crop salt tolerance, and proposed a "slope-threshold" model for σ:

$$\sigma(S_s) = \begin{cases} 1 & \text{for } 0 \leq S_s \leq S_t \\ 1 - m\,(S_s - S_t) & \text{for } S_t < S_s \leq S_z \\ 0 & \text{for } S_z < S_s \end{cases} \quad [3a]$$

S_t is the threshold value of S_s. Yields do not decline so long as S_s does not exceed the threshold S_t. The constant m is a slope, giving the rate of yield decrease per unit increase in soil salinity once S_s exceeds the threshold S_t. $S_z = [S_t + (1/m)]$ is the value of S_s beyond which yield is projected to be zero. Maas (1985) has recently recommended values for S_t and m for over 70 agricultural crops.

Although the slope-threshold model of Maas and Hoffman (1977) is a popular approach to quantifying crop response to salinity, other approaches are possible. The following two models, first suggested by van Genuchten (1983), have been shown (van Genuchten and Hoffman, 1985) to fit some crop salinity response data as well or better than equation [3a]. Rather than the piecewise linear response of the slope-threshold model, these models predict a smooth sigmoidal response of relative yield to salinity.

$$\sigma(S_s) = 1/[1+(S_s/S_{50})^p] \quad [3b]$$

$$\sigma(S_s) = \exp(a \cdot S_s - b \cdot S_s^2) \quad [3c]$$

S_{50} in equation [3b] is the value of S_s corresponding to $y_s = 0.5$, and p is a shape factor. The parameters a and b in equation [3c] are empirically determined constants. For $a>0$, the function $\sigma(S_s)$ reaches a maximum greater than one at some positive value of salinity. The maximum occurs at $S_s = a/2b$. This function could be of some use if the crop being considered responds positively to a slight salinity stress.

Calculating Crop Response to Water and Salt

Irrigating with saline water will cause some degree of salinization of the soil. This in turn will cause a decrease in crop yield relative to the yield under non-saline conditions. This reduced yield ought to be associated with a decrease in plant size and a decrease in seasonal E_t. But as E_t goes down, effective leaching will increase, mitigating the initial effect of the saline irrigation water. For any given amount and salinity of irrigation water, there will be some point at which values for yield, E_t, leaching and soil salinity are all consistent with one another. The yield at this point is the yield to be associated with the given irrigation water quantity and salinity. This thought process can be formalized to provide a procedure for calculating crop response to water and salt.

A key assumption necessary for the development of the procedure is that plant response to water and salt-induced stress is the same. Except for specific ion effects, this assumption appears reasonable (Meiri and Shalhevet, 1973), and has been used by others (Childs and Hanks, 1975). This assumption implies that the function $Y = \alpha(E_t)$ should be independent of the factor

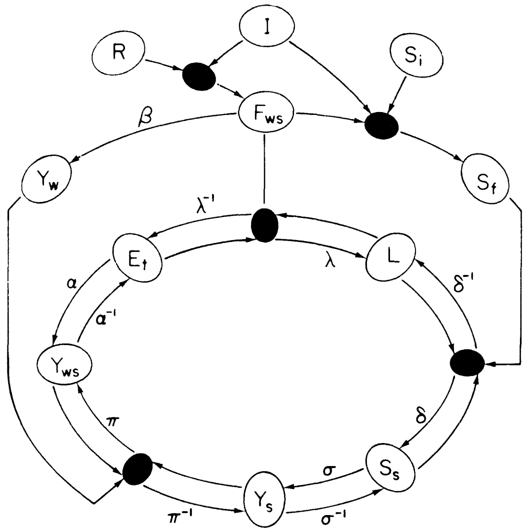

Fig. 3—Water-salinity-production function relationship map.

influencing the yield. The data of Hanks et al. (1978) for corn and of Hoffman et al. (1983) for tall fescue support this assumption. They each found that yield decreases due to salinity were accompanied by decreases in seasonal E_t, and that Y-E_t relationships were not affected by salinity treatment.

Suppose R, $\alpha(E_t)$, $\beta(F_{ws})$, and $\sigma(S_s)$ are known, and let Y_{ws} be the yield from the combined influences of water and salinity. From the definitions of Y_w and y_s, $Y_{ws}=\pi(Y_w,y_s)=Y_w \cdot y_s)$. The problem is to compute the yield Y_{ws} for given values of I and S_i. $F_{ws}=R+I$, $Y_w=\beta(F_{ws})$, and $S_f=S_i \cdot I/F_{ws}$. The relationships between the remaining variables form a closed circuit, as illustrated by the relationship map in Fig. 3. The variables are represented as nodes on a graph, and the pathways between nodes are labeled with the functions used to compute the variables. All of the variables on the closed circuit may be calculated once any one of them is known. Furthermore, the circuit can be traversed in either direction.

Suppose an estimate for L is given. Going in the clockwise direction, δ is used to compute S_S from L and S_f. σ computes y_s from S_s, and π gives Y_{ws} from y_s and Y_w. The inverse of the function α gives E_t. If all the variable values are consistent with one another, $\lambda(E_t,F_{ws})$ will equal L. In the counter-clockwise direction, λ inverse gives E_t from F_{ws} and L. α then gives Y_{ws}, which with Y_w implies y_s via π inverse. From y_s, σ inverse gives S_s, and if all values are consistent, the inverse of δ will give L from S_s and S_f. Thus, L can be defined as a recursive function of itself: L=f(L).

In the clockwise direction,

$$f(L) = \lambda \cdot \alpha^{-1} \cdot \pi \cdot \sigma \cdot \delta = \lambda\left([\alpha^{-1}(\pi[Y_w,(\sigma[\delta(S_f,L)])])],F_{ws}\right) \quad \ldots\ldots [4a]$$

while in the counter-clockwise direction,

$$f(L) = \delta^{-1} \cdot \sigma^{-1} \cdot \pi^{-1} \cdot \alpha \cdot \lambda^{-1} = \delta^{-1}\left[\sigma^{-1}(\pi^{-1}[(\alpha[\lambda^{-1}(L,F_{ws})]),Y_w]),S_f\right] \quad \ldots\ldots [4b]$$

In both equations [4a] and [4b], "·" denotes functional composition (defined by (g·h) (x)=g[h(x)]), and it is assumed that the required inverse functions can be constructed. Similar expressions could be written by starting with any of the variables in the circuit. Because of their simple algebraic forms, the functions λ, π and σ are easily inverted. Often α will also have a form that is easily inverted, but due to the complex forms for K given in equation [3], δ must be inverted numerically. For this reason, equation [4a] usually will be preferrable to equation [4b].

If either α or δ must be inverted numerically, the half-interval or bisection algorithm (Carnahan et al., 1969) is an excellent tool. Consider, for example, the problem of finding L for which $\delta(L,S_f)=S_s$, a known value. δ is monotone, and L is bounded by zero and one, so L may be found to within 0.03 with only four evaluations of δ.

Fig. 3 shows that if one of L, E_t, Y_{ws}, y_s, or S_s are known, the rest can be calculated directly. However, in constructing Y_{ws} from I and S_i, none of these will be known, and L=f(L) (or a similar equation for another variable) must be solved for L. The problem is a natural candidate for the successive substitution (or Picard iteration) algorithm (Carnahan et al., 1969). An estimate (L_j) is made for L, and the succeeding estimate (L_{j+1}) is computed from

$$L_{j+1} = (1-q) \cdot L_j + q \cdot f(L_j) \quad \ldots\ldots [5]$$

One hopes that the sequence generated by equation [5] will converge to the solution (q is a factor that will affect convergence). The convergence properties of equation [5] will depend on the functions composed to form f, but with q=0.5, it will converge for most realistic agricultural problems. It can be shown that if the derivative of f(L) is bounded and continuous, there is some range of values for q that will cause equation [5] to converge whether the initial estimate L_1 is close enough to the solution of L=f(L).

This approach to the construction of water-salinity-production functions is quite general, requiring no special assumptions about the forms of the functions involved. The solution technique of successive substitution (and bisection for functional inverses when necessary) is robust and fairly efficient.

After discussions of this topic with the author, Letey et al. (1985) developed a special case of the more general theory presented here, predicated on particular geometric forms for some of the functions involved. They validated their model against the data of Hoffman et al. (1983), finding good agreement between predicted and observed yield. Their work supports the validity of the concepts underlying both their (special case) model and the theoretical development presented here.

TABLE 1. FUNCTIONS AND CONSTANTS FOR EXAMPLE

Function	Note
$\alpha(E_t) = -0.34 + 1.34 \cdot E_t$	$0.254 \leqslant E_t \leqslant 1.0$
$\alpha^{-1}(Y_{ws}) = (Y_{ws} + 0.34)/1.34$	$0.0 \leqslant Y_{ws} \leqslant 1.0$
$\gamma(F_{ws}) = k \cdot F_{ws}^{2.5}$	$F_{ws} \leqslant F_{ws}^*$
$F_{ws} - 1.0$	$F_{ws} > F_{ws}^*$
$\beta(F_{ws}) = -0.34 + 1.34 \cdot (F_{ws} - k \cdot F_{ws}^{2.5})$	$F_{ws} \leqslant F_{ws}^*$
1.0	$F_{ws} > F_{ws}^*$
$\sigma(S_s) = 1/[1 + (S_s/5)^{3.5}]$	Corn, Grain

Constants: Symbol	Value(s)	Description
R	0.2 (0.0, 0.4)	Rainfall, relative to E_t^*
k	0.12 (0.00, 0.06, 0.08)	Coefficient in $\gamma(F_{ws})$
F_{ws}^*	1.19 (1.00, 1.07, 1.48)	Value such that $\beta(F_{ws}^*) = 1$, depends on k
d_p	0.9	Portion of $\gamma(F_{ws})$ that goes to deep percolation

EXAMPLE

To illustrate the foregoing theory, a simple example is constructed from available crop response data. The water response curves are based on the data of Stewart and Hagan (1973) for corn (grain). For this example, all water and yield data are expressed in dimensionless terms. The water variables E_t, F_{ws}, R, and I are all measured relative to E_t^*, and yields are expressed relative to $Y^* = \alpha(E_t^*)$, the maximum yield expected under non-saline conditions, water not limiting. Table 1 gives the primary functions and constants used for this example. The function $\beta(F_{ws})$ is illustrated in Fig. 4a. It has been assumed for this example that drainage is adequate and that fertility is managed so that yields do not decline as F_{ws} increases beyond F_{ws}^*, the value corresponding to E_t^* and Y^*. The power function form for $\gamma(F_{ws})$, with $k = 0.12$ and $r = 2.5$, fit Stewart and Hagan's (1973) observations reasonably well. It has been assumed that 90% of $\gamma(F_{ws})$ goes to deep percolation, so $d_p = 0.9$. The sigmoidal function equation [3b] was used to represent the response of corn (grain) to salinity. The values $S_{50} = 5$ and $p = 3.5$ will cause equation [3b] to exhibit a response similar to the slope-threshold response for corn as given by Maas and Hoffman (1977).

The results of the water-salinity-production function calculations for corn are shown in Fig. 4. An exponential root uptake function has been assumed, as recommended by Hoffman and van Genuchten (1983), and the rainfall value has been taken as $0.2 \cdot E_t^*$. Since rainfall is assumed to be non-saline, the salinity of the supplied water S_f varies with F_{ws}, and is lowest with small irrigation applications. As expected, simulated crop yield increases with increasing field water supply, but decreases as the salinity of the irrigation water increases. Note that even when F_{ws} is considerably below the crop water requirement E_t^*, the plant-soil system adjusts so that some leaching is predicted. Predicted steady state soil salinity, though, is highest for low values of field water supply.

The effects of varying certain elements in the model are shown in Fig. 5, for the case where the salinity of the irrigation water is given by $S_i = 4$ dS/m. Large values of k in the power function expression for $\gamma(F_{ws})$ correspond to

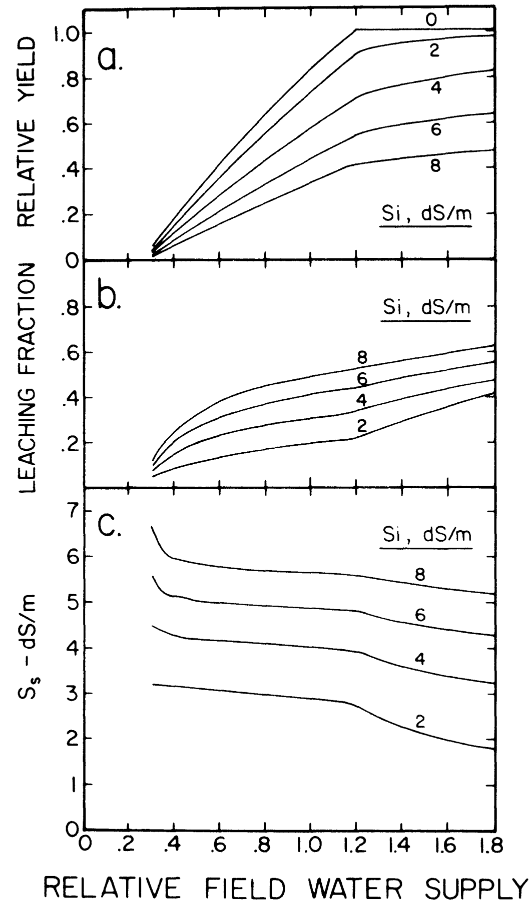

Fig. 4—Corn (grain) yield, leaching fraction and steady-state soil salinity as functions of F_{ws} and S_i, for the example case.

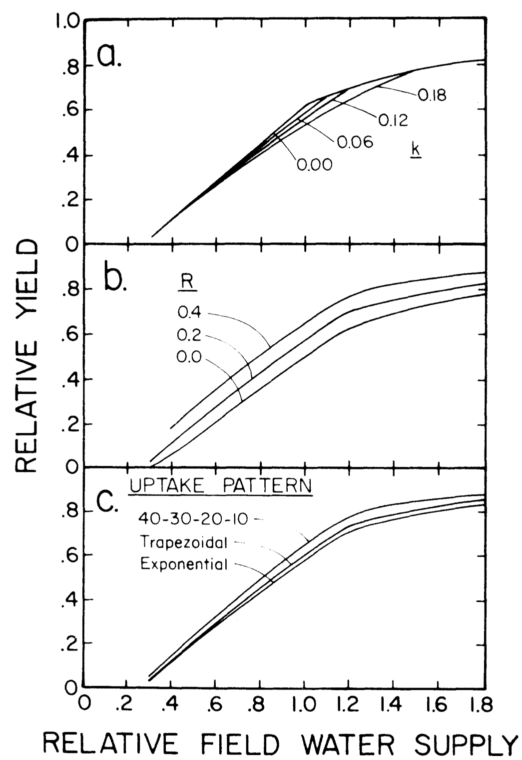

Fig. 5—Effect of k, R, and uptake pattern on the production function when S_i = 4 dS/m.

less efficient irrigation practices, in the sense that higher levels of F_{ws} are required to produce the same E_t. Fig. 5a shows that the same holds true when irrigating with saline water, even though the extra deep percolation contributes to leaching. Fig. 5b illustrates the effects of different amounts of rainfall. Without rain, F_{ws} must be completely supplied by irrigation, hence $S_f = S_i$. Higher rainfall increases yield because it lowers the average salinity of the supplied water. Fig. 5c shows the influence of the assumed root water uptake function. Yields are lowest for the exponential uptake pattern, and highest for the 40-30-20-10 pattern. These results are consistent with the findings of Hoffman and van Genuchten (1983) showing the effects of uptake pattern on average soil salinity.

SUMMARY AND CONCLUSIONS

Considerable work has been done regarding the response of agricultural crops to (non-saline) water. This response may be summarized in water production functions, relating crop yield to evapotranspiration or to field water supply, a variable which includes water from irrigation, rainfall, and soil moisture stored in the rootzone at the time of planting. These production functions do not consider any adverse effects from soil salinization which may occur when irrigating with saline water. Water-salinity-production functions, which relate yield to the quantity and salinity of applied water, would be very beneficial in the study and evaluation of water management practices wherever salinity is a potential problem.

Crop salt tolerance data, expressing relative yield as a function of soil salinity, are available for a wide variety of agricultural crops. Also available are steady state flow and transport models for predicting values of soil salinity when the leaching fraction and average salinity of applied water are known. These may be combined with crop water response data to produce water-salinity-production functions.

A model has been developed for constructing water-salinity-production functions based on our understanding of crop response to water and to salinity, and the leaching process. Key assumptions in the development of the model are (a) plant response to water deficit and salt-induced stress are the same, and (b) steady state levels of soil salinity are good indicators of salinity stress induced in the plant. The model is based on the observation that the soil-plant system can adjust to soil salinity by reduced yields, and hence E_t, to the point where yield, evapotranspiration, leaching and soil salinity are mutually consistent. The model is developed in a general way, not dependent on special forms for the water and salinity response functions.

The model theory is illustrated with an example based on data for corn (grain). While inadequate water and increasingly saline irrigation water decrease simulated yield, it is interesting to note that some leaching is predicted even when the field water supply is well below the normal crop requirement. The model suggests, of course, that deficit irrigation with saline water will lead to reduced yield, but not necessarily to uncontrollably high levels of soil salinity. Some empirical data supports the conceptual basis for this model, but further experimental tests of the model would be welcomed.

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