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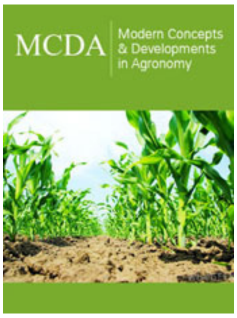
Mini Review

Application of Stress Forms of Richard's Equation in the Irrigation Deficit Scenarios and Dry Agriculture. Soil Stress Index Model (SSIMOD)

El-Shazly Mohamed Hegazy*

Ph. D. Natural Resources- Cairo University, Giza, Egypt

ISSN: 2637-7659



***Corresponding author:** El-Shazly Mohamed Hegazy, Ph. D. Natural Resources- Cairo University, Giza, Egypt

Submission: February 13, 2024
Published: March 27, 2024

Volume 14 - Issue 1

How to cite this article: El-Shazly Mohamed Hegazy*. Application of Stress Forms of Richard's Equation in the Irrigation Deficit Scenarios and Dry Agriculture. Soil Stress Index Model (SSIMOD). Mod Concep Dev Agrono. 14(1). MCDA. 000829. 2024. DOI: 10.31031/MCDA.2024.14.000829

Abstract

A stress form of Richard's equation was created, nominated, and discussed by the author. The logical model of soil stress index and soil water hydraulic capacitance will classify the types of water uptake under abiotic stressed conditions It's the moisture redistribution (bz) which makes the curvature of SSI becomes gradual and hence saves plant life as long as possible now and then each wetting drying cycle. It's the gaining factor which determines the moisture's sink should be applied in the deficit irrigation scenarios without causing a reliable reduction in crop yield and plantation properties. It's the soil water hydraulic capacitance which determines the type and amount of water and nutrients' uptake in accordance with stress, strain, and weathered controlled forces. Finally, It's the soil stress index which determines the type and amount of water and nutrients' uptake in accordance with water stress reduction function. The most interesting result is that the author found new valuable tools for assessing some environmental impacts of climatic changes on the agro ecosystem continuum under stresses of drought and salinity.

Keywords: Soil stress index; Plant stress index; SSIMOD; Drought and salinity

Introduction

Anthropogenic emissions of heat trapping greenhouse gases are causing adverse widespread effects on the Earth's climate. The shrinkages of glaciers and ice sheets, earlier breakup of river and lake sheets, shifts in geographic distribution of planta and animalia especially mammals, sea rise, saline water intrusion, intense heat waves, droughts, salinity, desertification are some examples. The adverse effects of global climate changes and associated risks depend on mitigated and adapted actions in each proposed managerial scenarios by IPCC to deal with them. The agro-ecosystem continuum will receive precedential waves of drought, salinity, heat shocks, and wildlife shifts or migration due to global climatic changes. Some region will be mammalian uninhabitable due to the same reason [1]. In the incoming section we will focus the macroscopic point of view on a recent achieved model, SSIMOD [2]. Its equations, assumptions, and applications.

Soil Stress Index Model (SSIMOD)

The managerial practices of agro-ecosystem continuum under abiotic stressed conditions involve the use of silicate fertilizers for enhancing soil physical properties [3], yield, and planation. A new form of Richard's equation is achieved and discussed. The stress form of Richard's equation is a soil stress index (SSI) based [2]. The Soil Stress Index Model (SSIMOD), the conceptual macroscopic model, expresses the sink/ source terms by the assumption of discharge /recharge of the soil capacitor in-between processes of water uptake and water infiltration respectively [4].

The author found that the term plant water uptake (S) is the product of multiplying the soil stress index (SSI) with a new term called soil water hydraulic capacitance (β). Hence, S=

SSI * β. A strong correlation was appeared between stress indices of plant and soil. The latter empirical correlation will be opening the gate to a new way of assessing the plant response to environmental abiotic stresses using the stress form of Richard's equation. As PSI is the dependent variable of the SSI, predictions of PSI under temporal, spatial, and tempo-spatial variabilities can be headed and discussed simply. The control finite volume assumptions were used to achieve the numerical solution of the new stress form equation. Water redistribution (bz) is also a newborn of the stress form. Finally, the gaining value (bt), representing the amount of water reached the vadoze root zone depth under abiotic stressed conditions in relation to the optimum wetness, is gained [5].

The recent discovered four terms from the new achieved stress form control the type and amount of plant root water and nutrient uptake from the variably saturated zone. The governing forces are stress, strain, and weathered controlled The author would like to nominate the latter four discovered terms as Hegazy Abiotic Stressors' Parameters (HASP) Managerial practices under the studied abiotic stressed conditions involve silicon foliar application. The abiotic stressors' parameters are being used in assessing the impacts of combined drought and salinity on plants' yield and plantations under silica fertilization. Silicon proved that it is the plant first aid for enhancing the agricultural production under unfavorable abiotic stress conditions of global climatic changes [5].

Soil Stress Index as a Mathematical Model (SSIMOD)

$$SSI = lim_{\theta r \to 0}(\frac{Se}{Se*}) \qquad Se = \frac{\theta - \theta r}{\theta s - \theta r}$$

$$SSI = \lim_{\theta r \to 0}(\frac{(\frac{\theta - \theta r}{\theta s - \theta r})}{(\frac{\theta * - \theta r}{\theta s - \theta r})}) \quad SSI = \lim_{\theta r \to 0}(\frac{\theta - \theta r}{\theta * - \theta r})$$

$\theta = \theta_{mo} + \theta_{im}$ Dual Porosity theory [6]

$$\theta r \le \theta PWP \le \theta_{im}$$

Assume that the immobile moisture content is redundant in water flow researches and the soil moisture at permanent wilting point is redundant in root water uptake. The hydraulic parameter of Van-genuchten n, m, and α could be estimated if SSI is known (reverse solution) or from HYDRUS 1D [6].

$$SSI = \lim_{\theta im \to 0}(\frac{\theta - 0}{\theta * - 0}) = \theta / \theta * = h / h * = \Psi / \Psi *$$

$S_e = (\frac{\theta - \theta r}{\theta s - \theta r}) = (1 + (\alpha \Psi)^n)^m$ [7]

Similarly,

$$SSI = \frac{(1 + (\alpha \Psi)n)m}{(1 + (\alpha \Psi *)n)m} - (m = 1/n)$$

$$c(h)\frac{dh}{dt} = \frac{d}{dz}\left(k(h)\frac{dh}{dz} + k(h)\right) - S(z,t)$$

$$S(z,t) = \alpha(h, hs, z, t) S \max$$

$$T_a(t) = \alpha(h, hs, t) T_p(t)$$

$$T_a(t) / T_p(t) = \alpha(h, hs, t)$$

$$S(z,t) / S_{\max} = \alpha(h, hs, z, t)$$

$$c(h)\frac{dh}{dt} = \frac{d}{dz}\left(k(h)\frac{dh}{dz} + k(h)\right) - \alpha(h, hs, z, t) S \max$$

$$SSI(h, hs, z, t).\alpha.\alpha(h, hs, z, t)$$

$$SSI(h, hs, z, t) = \mu \alpha(h, hs, z, t)$$

$$\alpha(h, hs, z, t) = \frac{SSI(h, hs, z, t)}{\mu}$$

$$c(h)\frac{dh}{dt} = \frac{d}{dz}\left(k(h)\tfrac{dh}{dz} + k(h)\right) - \frac{SSI(h, hs, z, t)}{\mu} S \max$$

$$SSI = \frac{h(z,t)}{h*}$$

$$c(h)\frac{dh}{dt} = \frac{d}{dz}\left(k(h)\tfrac{dh}{dz} + k(h)\right) - \frac{h(z,t)}{(h*)u} S \max$$

$$\omega = \frac{S \max}{(h*)\mu} \quad \beta = \frac{S \max}{\mu}$$

$$c(h)\frac{dh}{dt} = \frac{d}{dz}\left(K(h)\frac{dh}{dz} + k(h)\right) - \omega h(z,t)$$

$$c(h)\frac{dh}{dt} = \frac{d}{dz}\left(K(h)\frac{dh}{dz} + k(h)\right) - \beta SSI(z,t)$$

$$\beta SSI(z,t) = \frac{d}{dz}\left(K(h)\frac{dh}{dz} + k(h)\right) - c(h)\frac{dh}{dt}$$

$$SSI(z,t) = 1/\beta[\frac{d}{dz}\left(K(h)\frac{dh}{dz} + k(h)\right) - c(h)\frac{dh}{dt}]$$

$$SSI(z,t) = 1/\beta[\frac{d}{dz}\left(K(h)\frac{dh}{dz} + k(h)\right) - \frac{d\theta}{dt}]$$

$$SSI(z,t) = 1/\beta[\frac{d}{dz}\left(D(\theta)\frac{d\theta}{dz} + k(h)\right) - \frac{d\theta}{dt}]$$

Where: Smax, S: Potential yield and actual yield respectively. h*: Total soil potential at field capacity capacity (cm. H_2O).h : Total soil potential at each point (cm H_2O).t, z: Time and depth respectively (Day, cm). μ: Direct proportional coefficient between SSI and α (h, **Ψ**) and can be estimated empirically. SSI: Soil stress index. α (h, **Ψ**): Plant Stress Index. c(h): Soil water holding capacity (cm^{-1}). K(h): Unsaturated soil hydraulic conductivity

$$c(h)\frac{(dh)/h*}{(dt)/h*}dz = \left(k(h)\frac{(dh)/h*}{\frac{dz}{h*}} + K(h)\right) = c_{(h)}\frac{dSSI}{(dt)/h*}dz = \left(k(h)\frac{dSSI}{b(z)} + K(h)\right)$$

Where: b (z) = (dz/h*) = (L-L)/ $L^3=L^{-2}$

Two proposed nominations for the term b(z) in the variably saturated conditions. The first, the water redistribution due to the sink/ source term. As root distributions should follow water redistributions, the proposed second nomination is the root distributions seeking the optimality in soil moisture regimes (l_{-2}). z1 water depth at h1, z2 water depth at h2, Δz= the change in water depth during categorizing the energy states of soil water by plant's root to water. b (t) = k(h)/h*= (l/t)/l^3= t^{-1} l^{-2} . I would like to nominate the term b(t) as the gaining value of moisture per time (t) and root domain(l^{-2}) due to the ability of soil to conduct water toward a control volume in the root domain under the driving forces of gravity and hydraulic gradient or moisture deficits. A numerical example, if the unsaturated hydraulic conductivity equal 2m/hr. and water potential at field capacity equal 2-meter head then it takes an hr. to gain the relative moisture optima due to the ability of soil to conduct water under the latter driving forces. Hence, SSI, β, b(t), and b(z) are new valuable tools for assessing some environmental impacts of global climatic changes on the agro ecosystem continuum under abiotic stressors of drought and salinity.

$$\left(k(h)\frac{dSSI}{b(z)}+K(h)\right)=k(h)(\frac{dSSI+b(z)}{b(z)})$$

$$c_{(h)}\frac{dSSI}{dt}dz=\left(\frac{K(h)}{h*}\right)\left(\frac{dSSI+b(z)}{b(z)}\right)=c_{(SSI)}\frac{dSSI}{dt}dz=b(t)\left(\frac{dSSI+b(z)}{b(z)}\right)=\frac{b(t)}{b(z)}\left(dSSI+b(z)\right)$$

$$c_{(SSI)}\frac{dSSI}{dt}=[\frac{b(t)}{b(z)}(dSSI+b(z))]\frac{d}{dz}-\beta.SSI \quad (1)$$

$$c_{(SSI)}\frac{dSSI}{dt}=[k(h)(dSSI+b(z))]d/dz^2-\beta.SSI \quad (2)$$

$$c(SSI)\frac{dSSI}{dt}=[k(h)\frac{(dSSI+b(z))}{dz}\frac{d}{dz}]-\beta.SSI \quad (3)$$

Equations (1, 2, and 3) will be nominated as the stress forms of Richard's equation where: c(SSI): water holding capacity(t^{-1}), SSI: Soil stress index, β: Soil water hydraulic capacitance, b (t) = k(h)/h*= (l/t)/l^3= t^{-1} l^{-2} . The gaining value of moisture per time and root domain due to the ability of soil to conduct water toward a control volume in the root domain under the driving forces of gravity and hydraulic gradient or moisture deficits. b(z) = (dz/h*). The root distribution seeking the optimum wetness because to moisture deficit in the domain (l^{-2}), z, t: time and depth, respectively (Figure 1).

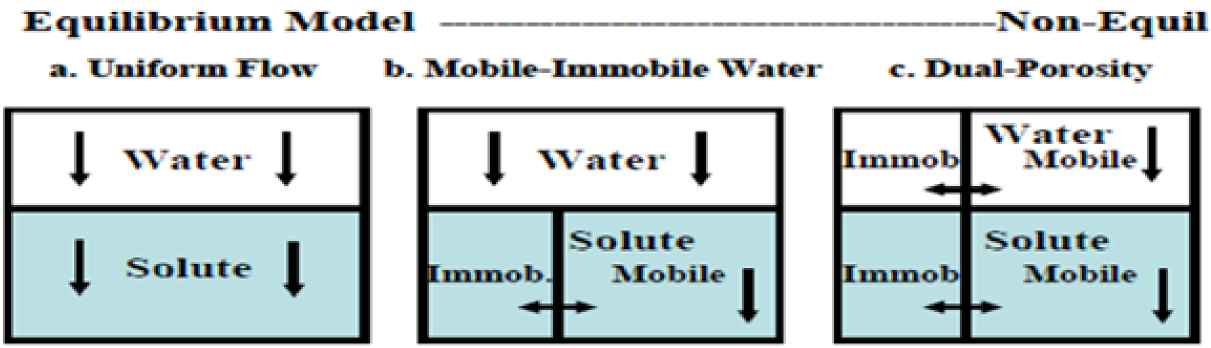


Figure 1: Conceptual physical nonequilibrium models for water flow and solute transport. In the plots, θ is the water content, m is mobile phase, im is immobile phase, M is soil matrix, and f is soil fracture respectively; c is concentrations of corresponding regions, with subscripts having the same meaning as for water contents, while S is the total solute content of the liquid phase [6].

Discussion

The soil stress index model is a macroscopic mathematical conceptual model. SSIMOD could be calculated based on the concepts of total soil water potential. Hence, it may be either additive (ASSIMOD) or multiplicative (MSSIMOD). Under the abiotic stressed conditions, SSIMOD assumes that plant follow the bath which saves its consumed energy during navigating soil system, categorizing energy states of soil water, and seeking the most available water to uptake It assumes a dependent root system where the moisture deficit in some parts of root domain is either partially or fully compensated from the yield value of moisture optima in other parts. There are three ways of compensation: The water redistribution (bz) after gaining the moisture, root distribution during categorizing the energy states of soil water to preferably uptake the most available water, and overall total water potential of the dependent root sap system. SSIMOD allows studying the prediction of values of plant stress index temporally and spatially by using the corresponding values of soil stress index [5]. SSIMOD is based on a hydrodynamic approach. This is because it assumes that water flow's governed passively by gradients of water potentials between soil, plant xylem, and atmosphere at a rate controlled by the water paths' hydraulic resistances. Therefore, it requires the input variables of the Transpiration Rate (Tc), total soil water potentials (πt), and root distribution (bz). Each number of one parent material homogeneously packed finite control volumes forms a layer. The layer is a capacitor recharged by the sources and discharged by the sink [4]. Furthermore, SSIMOD is found to have an application in managing the agro-ecosystems recycle the liquid emissions or use the poor water quality in agriculture development [8]. It's the moisture redistribution (bz) which makes the curvature of SSI becomes gradual and hence saves plants life as long as possible now and then each wetting drying cycle. It's the gaining factor which determines the moisture's regimes should be adopted in the deficit irrigation scenarios without causing a reliable reduction in crop yield and plantation properties. Finally, it's the soil stress index or soil water hydraulic capacitance which determines the type and amount of water and nutrients' uptake in accordance with stress or stress, strain, and weathered controlled forces, respectively (Figure 2).

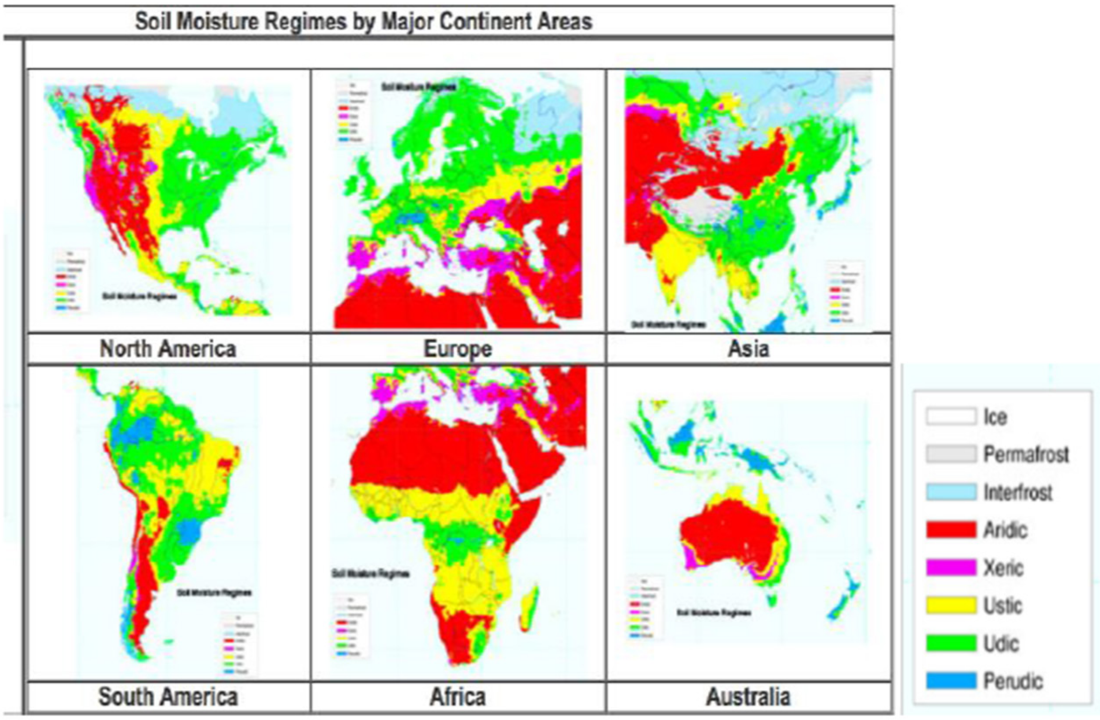


Figure 2: Worldwide soil moisture regimes map by continent. (Images courtesy of the USDA-NRCS, edited by UNL) 6.10 - Soil Moisture Regimes | Soil Genesis and Development, Lesson 6 - Global Soil Resources and Distribution - passel (unl.edu).

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