A Soil-Plant-Atmosphere Continuum Simulation Interacts with the Regional Environmental Scenario

—To control the salinization in agriculture—

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1. Introduction

The salinization is one of the most important issues for agriculture in arid and semiarid area. According to the report of Lower Seyhan Irrigation Project, fourth stage of development area ($4*10^8$ m^2) is problematic for high water table, salinity and alkalinity (sodicity), and water logging. The global warming might provide higher the sea water level. The higher the sea water level, the deeper intrude of seawater into land. The development of Seyhan and Ceyhan delta area accompanied with drier the damp land might provide further intrusion of seawater. Hence it would be essential to have a proper plan for development and usage of water in such tricky area.

The other hand, there are some aquifer, which total volume is $55*10^{10}$ m^3, in Seyhan and Ceyhan river basin. Plant production with irrigation on the aquifer should take care of salinization, since irrigation to the shallow aquifer might commit the upward water movement.

Multi-disciplinary research project would be possible to share and to integrate the result in many aspects, and to feed back of them. This paper focuses on the role of vegetation activity, in the concept of Soil-Plant-Atmosphere Continuum (SPAC), to control the salinization in Mediterranean coastal area, Turkey.

2. Methodology

Because of irreversible change, one is not able to carry out climate change and/or salinization experiment in the field. Hence a numerical simulation would be the proper method to discuss salinization. Though, bear in mind, one should have measured data in the field as a ground truth, and for the evaluation of the numerical results, i.e. evapotranspiration rate, development of root zone, leaf area index, water content, height of groundwater table and so on.

Considering time and space, the difficulties arise in this SPAC system. The ground data varies in space, but is relatively stable in time. The inverse modeling is the admirable methods for the parameter optimization of SPAC simulation (Dam, 2000).

3. Model Description

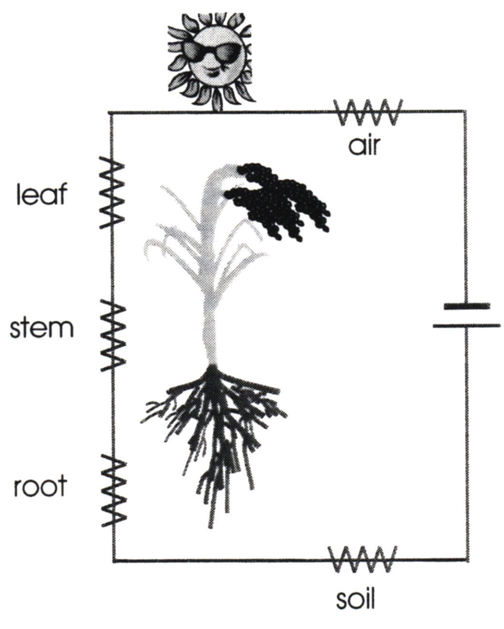

Fig. 1 Electrical analog of the liquid and vapor phase water movement in soil-plant-atmosphere continuum system.

Fig. 1 shows the electrical analog of the liquid and vapor phase water movement in SPAC system. Water potential plays a key role in this system. Resistances in this circuit are reciprocal numbers of each permeability, and vary on soil, plant and climate condition.

We selected SWAP program (Dam, et al., 2000) to evaluate the impact of climate change on agricultural systems, because of the reliability of SWAP model, i.e., physically based deduction model, reasonably simple to use and one is able to improve lots of options as sub-routines. Though, until now, the object area of this study is $4*10^8$ m^2, SWAP model has only been applied to laboratory columns, lysimeters and field scale (Aoda and Yoshida, 1995; Dam, 2000), never in river basin scale. For the parameterization by using the inverse method, one would succeed to determine the averaged field-effective parameters (Feddes et al., 1993), and would be able to treat the objective area as virtual integrated lysimeters.

4. Numerical Approach

Spatial difference of water potential causes movement of soil water in any phase. Extended Darcy's equation is used to describe those water fluxes in soil, root, xylem, stomata and air. In SWAP model, movement of soil water is written as:

$$q = -K\frac{\partial H}{\partial z} \tag{1}$$

where q is soil moisture flux density (positive upward, cm d^{-1}), K is hydraulic conductivity (cm d^{-1}), H is hydraulic potential (cm), which is sum of matric potential and gravitational potential, and z is vertical coordinate with origin at the soil surface, taken positive upward. Considering mass conservation in the infinitely small volume, the continuity equation is derived for soil water:

$$\frac{\partial \theta}{\partial t} = -\frac{\partial q}{\partial z} - S \tag{2}$$

where θ is volumetric water content (cm^3 cm^{-3}), t is time (d) and S is macroscopic soil water extraction rate by plant roots (cm^3 cm^{-3} d^{-1}). Hence the flow of water in a soil-root system would be described as:

$$C(h)\frac{\partial h}{\partial t} = \frac{\partial}{\partial z}\left[K(h)\left(\frac{\partial h}{\partial z}+1\right)\right] - S_a(h) \tag{3}$$

where h is water potential (cm), negative in unsaturated soil; C (=dθ/dh) is specific water capacity and is differential soil water characteristic curve. In unsaturated root zone, specific water capacity is heavily affected by hysteresis. Hysteresis should take into account in SWAP simulation, especially in root zone (Aoda and Yoshida, 1995).

The actual root extraction rate is described as:

$$S_a(z) = \alpha_{rw}\alpha_{rs}S_p(z) \tag{4}$$

where α_{rw} (-) and α_{rs} (-) are the reduction factors due to water deficit and salinity stresses, respectively and $S_p(z)$ is possible root extraction rate by plant in the optimal water condition. Integration of $S_a(z)$ over the rooting depth, from $-D_{max}$ to zero, yields the actual transpiration rate T_{act}.

$$T_{act} = \int_{-D\max}^{0} S_a(z)dz \tag{5}$$

where we assume that water storage in the plant body is small enough to neglect.

The Final yield of plant production is simply directly proportional to the total transpiration

$$Y = AW \tag{6}$$

where Y is plant yield (Kg ha^{-1}), W is cumulative plant transpiration (cm) and A is the water use efficiency depended on the plant species and environment. Though we have enough experience to simulate the plant production on agricultural land, we have lack information about actual evapotranspiration from natural vegetation. When we focus on water balance in mountainous area, it would be problematic.

With optimizing every coefficient for soil and plant in those equations under the present climate and groundwater condition, one would be able to predict the water balance salt accumulation and plant yield in various climate scenarios.

5. Interdisciplinary Aspects

Evaporation from vegetation interacts with the regional climate and water condition. A few climate studies provide the evidence that vegetation and other land surface properties may directly affect the atmospheric boundary layer (Feddes, 2001). The concentration of mineral in the water strictly affects to root water extraction. Plant is not always passive to the surrounded environment, sometimes plays in active in the severe conditions, i.e. water lift and using stress signals (Kramer, 1988; Johnson et al., 1991). Plant might have the critical high temperature for the flowering. We should solve above mentioned problems with strong team work.

6. References

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