11.4 \hspace{1cm} \textbf{AN ANALOGIC MODEL OF WATER EXTRACTION BY GRASS ROOTS}

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1. INTRODUCTION

The plant transpiration is the major water balance component in vegetated soils. Fluxes along the soil-plant-atmosphere continuum are regulated by above ground plant properties, like the leaf stomata, which can regulate plant transpiration when interacting with the atmosphere and below ground plant properties like depth, distribution, and activity of roots as well as soil physical properties like water potential, water content and hydraulic conductivity (Jackson et al., 2000). The role of soil moisture within the soil-plant-atmosphere system depends on the soil moisture reservoir size and the availability of water in that reservoir, which in turns depends, in part, on the texture and structure of soil and the characteristics of the root system (Feddes et al., 2001).

There are two broad classes of modeling approaches for the root water uptake: the microscopic approach that considers the convergent radial flow of soil water toward and into the roots, taken as a uniform root system by qr = q′ \cdot \Delta \cdot z.  
A simulation model can be developed from the first equation combined with an analogic macroscopic root extraction function (eqn. 3):

\[ \partial \psi_s / \partial t = \partial \psi_p / \partial t = (\psi_p - \psi_s) / (\psi_p - \psi_{\text{rs}}) \] (3)

where \( \psi_p \) is the plant water potential, \( \psi_s \) the soil resistance (\( r_s = b/k \)), and \( b \) the root distance parameter (b=ln(\( v_2/v_1 \)) / \( 2 \pi L_z \)).

A simulation model was used to derive a set of estimates for these 3 parameters.

2. DATA AND METHODS

The experiment was carried out at the University of São Paulo / Escola de Agricultura Luiz de Queiroz, county of Piracicaba, São Paulo, Brazil, located at 23°S and 47°W, at an altitude of 580m. The climate is Cwa according to Köppen’s classification with a typical rainy season from October to February. Annual average air temperature is 21°C, and average rainfall is 1250mm.year⁻¹.

Vegetation cover is short grass (\textit{Paspalum notatum}), with 15cm height. The mass distribution of the root system, fitted to field data collected at each 20cm, is: w = 0.0034 exp -0.014 z [g.cm⁻³].

The soil is a dark red latosol (\textit{Oxic Paleudalf}), 2.2m depth, bulk density 1.46 g.cm⁻³, and granulometry 35.2% sand, 19.5% silt, and 45.4% clay. The fitted soil water retention curve, obtained in laboratory using a pressure plate, is: \( \zeta = 2.71 \cdot 10^7 \exp ^{-34.36 \cdot \theta} \) [cm], and the fitted soil hydraulic conductivity curve, obtained under field conditions using the method of

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\[ \partial \psi / \partial t = \partial \psi / \partial z \] (1)

where \( \theta \) is the volumetric water content in the soil, t the time, z the soil depth, k the soil hydraulic conductivity, \( \dot{\xi} \) the soil matric potential, and \( \eta \) the root extraction rate. The single root model or microscopic approach (Federer, 1979) is the analytical solution for \( \partial \psi / \partial t = 1/v \partial \psi / \partial \psi \) i.e.:

\[ \dot{q} = -b(0)/k(z) - rr(0) \] (5)
Average rates of water extraction by roots, for 20 cm soil layers, were estimated from 3 \( \theta \) profiles, measured with a neutron probe at 3 days interval, in a dry sequence of 81 days, on August, September and October, by:

\[
\int_{z_1}^{z_2} \int_{r_1}^{r_2} q(z) dz dt = \int_{r_1}^{r_2} \left( q_{z_1} + q_{z_2} \right) dt - \int_{z_1}^{z_2} \left( \theta / \partial t \right) dz dt \quad (6)
\]

where \( \partial \theta / \partial t \) (eqn. 1) is solved using a forward finite difference method.

3. RESULTS AND DISCUSSION

Average water potentials in the soil (\( \psi_s \)), root (\( \psi_r \)), and plant (\( \psi_p \)) during the 27 dry periods of 3 days are shown in figure 1. \( \psi_s \) ranged from 1000 to 8000 cm. \( \psi_p \) is almost constant (\( \sim 3400 \) cm) until \( \psi_s = -3400 \) cm (17th period), increasing exponentially after this point, following \( \psi_r \).

Average estimates of root distance \( b(0) \) and root resistance \( r(0) \) were 2 ± 0.4 cm and 18000 ± 4000 days. The soil \( r_s = b/k \) and root \( r_r \) resistances, as well the total resistance \( r_s + r_r \) to water flux from soil to plant, for the 27 periods of 3 days, are shown in figure 2.

Root resistances are almost constant (8200 days) and predominate until soil water potential \( \psi_s = -4300 \) cm or \( k = 1.2.10^{-4} \) cm.day\(^{-1} \) (20th period), increasing exponentially after this point. These results in agreement with Reicosky & Ritchie (1976), Federer (1979), and Zur et al. (1982), indicate that the root resistance to water transport is much greater than the soil resistance in a wide range of soil water content. These findings emphasize the need to consider root resistance in water uptake calculations when using equations that evaluate water potential gradients along the water flow paths.

4. REFERENCES

Desborough, C. E., 1997: The impact of root weighting on the response of transpiration to moisture stress in


