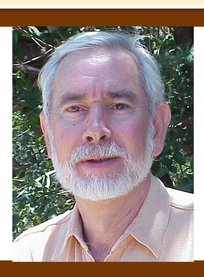
Modelling the Potential Root Water Extraction Ratio in soil: application to sugarcane on the island of Reunion.



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Aims

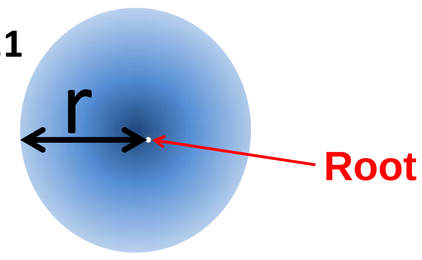
The study set out to model the potential root extraction ratio in soil (PRER), by counting root intersections (RI) obtained using the trench-profile method (TPM), to infer the spatial distribution of sugar cane root length densities (RLD) and root distances (RD).

PRER model

PRER: Potential Root Extraction Ratio
Estimating the maximum fraction of soil that can be used by the plant, via its roots, taking into account:

- **(i) the average distances (RD) between captor organs, per volume of soil,**
- **(ii) the maximum distance (r) of water (W) movement to the root in the soil,**
- **(iii) a simple linear W depletion between the root and r following earlier tests (Fig.1).**

Fig.1



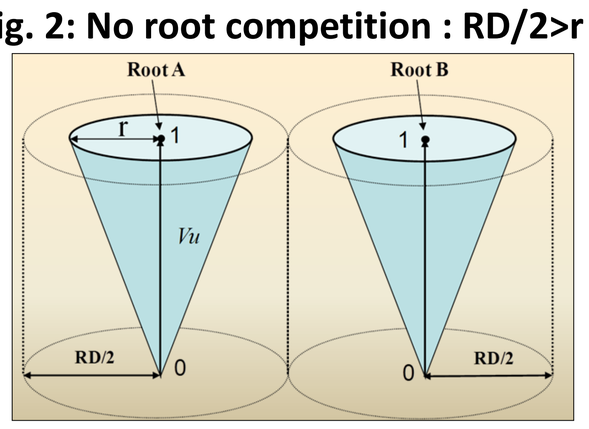
A depletion zone for the fraction of available W tends to become established around the root. After a certain period of extraction without replenishment, the root has depleted all the useful W.

PRER: Ratio between the volume of soil potentially accessible to the root for W uptake (Vu) and the volume of soil assigned to that root (V_t):

$$\mathrm{PRER} = V_u / Vt \quad \textbf{Eq.1}$$

V_t is a cylinder around each root with a radius equal to the half-distance between the roots (Fig.2).
V_u is a cone, with a base π* r² and height (1) which corresponds to the maximum available fraction of soil for W at the root surface area.

Fig. 2: No root competition : RD/2>r



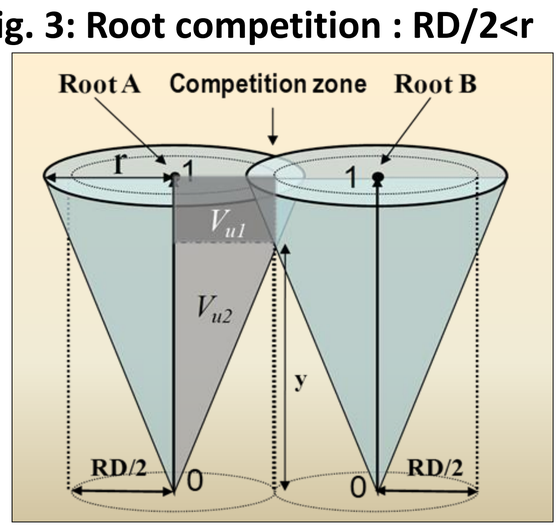
For a single root or when there is no competition between roots, i.e. if the half-distance between roots exceeds r (RD/2 ≥ r), then Fig. 2 and Equation 1 give eq.2 :

$$\mathrm{PRER} = \frac{4}{3} * \left(\frac{r}{RD}\right)^2 \quad \textbf{Eq.2}$$

If RD/2 ≤ r, there is competition between 2 roots to capture water (Fig.3).
V_u has two components V_{u1} (cylinder) and V_{u2} (cone).
The y value, ranging from 0 to 1, defined the limit of competition zone for soil W depletion and also defined the limit between V_{u1} and V_{u2}. V_{u1} and V_{u2}.
Then, PRER can be reduced to eq.3 (Chopart 1999):

$$\mathrm{PRER} = 1 - \mathrm{RD}/(3 * \mathrm{r}) \quad \textbf{Eq.3}$$

Fig. 3: Root competition : RD/2<r



<u>PRER tends towards 1 when roots are very close to each other or when the migration distance is very great.</u>
It is assumed in results that the maximum distance for water migration into the soil to the root (r) was 0.05 m for local soil conditions and according to previous studies (Chopart 1996, Lang and Gardner 1970).

Methods and Key Results

In Reunion Island, RI of sugarcane values were counted using a grid with a 5 x 5 cm mesh, down to a depth of 4 m over 1.5 m wide soil profiles. RLD were calculated from RI (Chopart et al. 2008) and RD from (Newman1969) using Racine2 software (Chopart et al. 2009).

Fig.4: RLD (cm/cm³) **Fig.5: PRER**

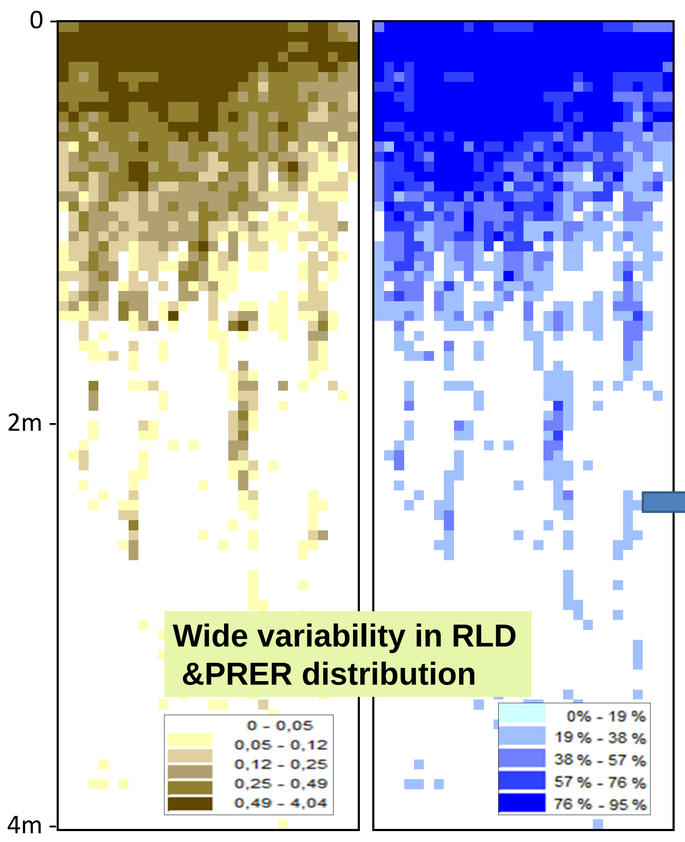


Fig.6: Profiles of RLD (cm/cm³) & PRER (0-1)

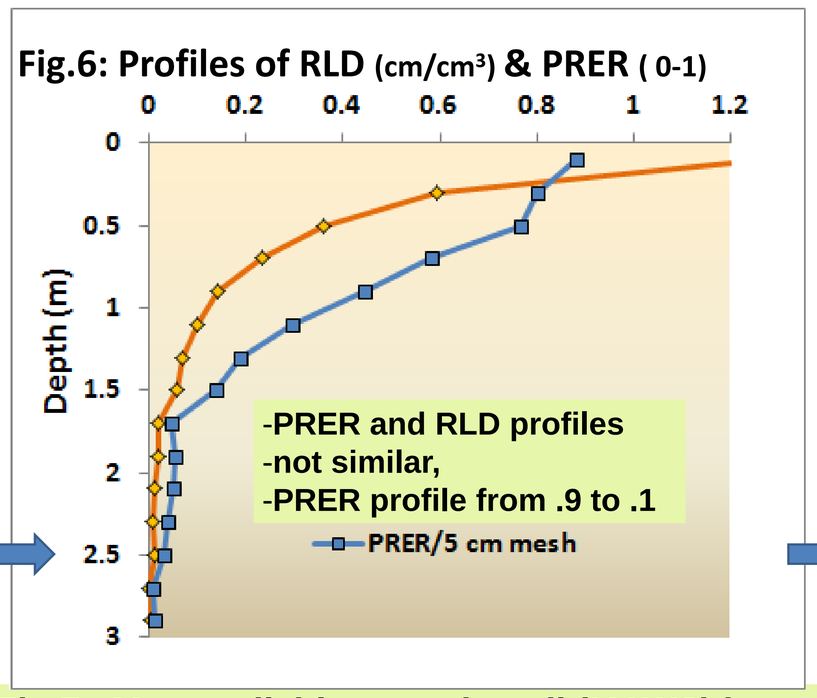


Fig.7: Profile of MAWS (mm/cm soil depth)

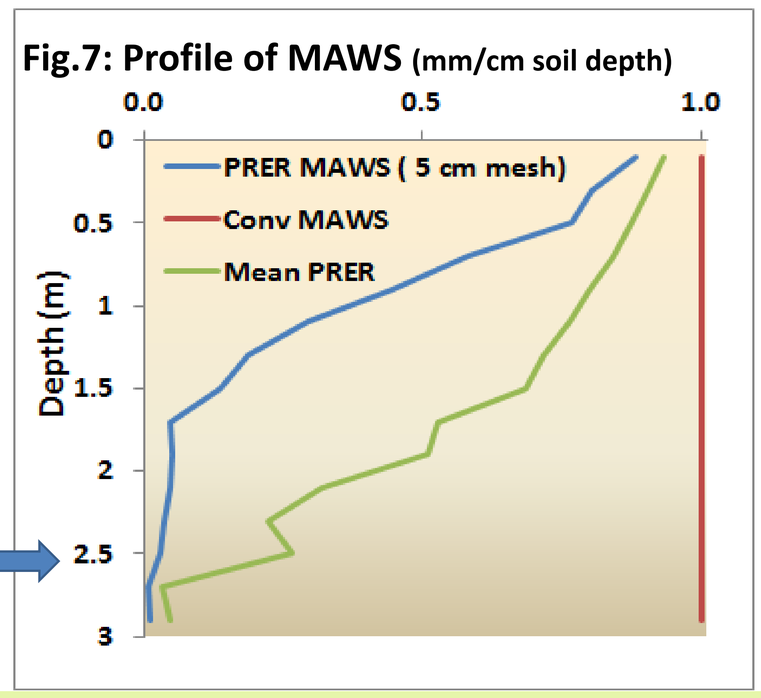


Fig.7 : Max available water in soil (MAWS) is overestimated if calculated from RLD and the PRER mean values (green line). It is very overestimated if it is assumed that available W is not dependent on the root system, only on soil, i.e 1mm/cm of soil depth (red line). The best estimating is using PRER mapping (blue line).

The PRER approach provides an estimation of the biologically maximum available water in soil using the distribution of the root system.
It may be a better indicator of crop functioning under either water stress or nutrient deficit.

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