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

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).

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 (Vt):

\[
PRER = \frac{V_u}{V_t} \quad \text{Eq.1}
\]

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

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

\[
PRER = \frac{4}{3} \left( \frac{r}{\text{RD}} \right)^2 \quad \text{Eq.2}
\]

If \( \text{RD/2} < r \), 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):

\[
PRER = 1 - \frac{\text{RD}}{3 \times r} \quad \text{Eq.3}
\]

PRER tends towards 1 when roots are very close to each other or when the migration distance is very great.

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).

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.