RACINE2: A software application for processing spatial distribution of root length density from root intersections on trench profiles.

Jean-Louis Chopart, Lionel Le Mézo, Mickaël Mézino

Cirad, UPR Annual Cropping Systems Research Unit, Saint Pierre 97410 (France)
Corresponding author: chopart@cirad.fr

ABSTRACT

A field method has been developed to quantify root length density (RLD) from root intersection density (RID) measured on a trench-profile, using modelling RID-RLD relationships. For 2D spatial distribution mapping of RID (at 5-cm scale for example), the large amount of data is processed and converted into RLD and root distances (ARD) through modeling. Calculations and RLD mapping can be performed quickly using a new freeware: RACINE2, tailored to this field method. The software also allows a simple modeling of potential root exploration ratio in the soil (PRER) taking ARD into account. The software contains published models calculating RLD from RID for several crops (maize, sorghum, sugarcane, rice), ARD from RLD and PRER from RD. Models may be changed or added into RACINE2. RLD, ARD and PRER are calculated for each spatial unit. They can be mapped. Data can be exported to a spreadsheet or a surface mapping software for further analysis. It is also possible to import data into RACINE2 from a spreadsheet. *RACINE2* thus makes studies about root-soil interactions, root growth and root uptake easier. Some examples of field results calculated by RACINE2 are presented (RLD, ARD and RER profiles and maps). They point out differences of PRER when taking (or not taking) into account 2D spatial root distribution. Taking into account spatial variability of root system in relation with soil characteristics may be important for root water and nutrient uptake in field conditions.

KEYWORDS

Trench-profile method, Root study software, Root length density, Root distribution.

INTRODUCTION

The spatial distribution of crop roots is a key factor for uptake of water and nutrients; and development of the roots in the soil is highly dependent on the latter's physical and chemical properties, which can have significant spatial variability. The spatial distribution of a plant's root system thus reflects the soil's constraints and the plant's ability to ensure its water and nutrient supply. There is a method for studying this root distribution in the soil, which consists in counting intersections between a trench-profile and the roots, pinpointing these intersections in the profile spatially with the aid of a mesh-grid (Chopart, 1999, Chopart et al., 2009). By using this method, the user obtains the density of the intersections and their spatial distribution (depth, gradients, heterogeneous features). The main root characteristics can then be established via modeling, beginning with the root length density (RLD). Models for estimating RLD from root intersections have already been proposed for maize (Chopart and Siband, 1999), sugarcane (Chopart et al., 2008), sorghum (Chopart et al., 2008) and upland rice (Duserre et al., 2009). One of this method's constraints is the large amount of data involved, and using a simple spreadsheet for the calculations is rapidly inconvenient; which is why an application for processing root data has been created. After an overview of the main features of this software, RACINE2, a few examples of results will be presented.

OVERVIEW OF THE TOOL

RACINE2 (Fig. 1) mainly enables: (i) entry of spatialized data of intersections between roots and a soil plane (RID), (ii) from these intersections, calculation of root length densities (RLD), distances between roots (ARD) (Newman, 1966), and the potential root exploration rate in the soil (PRER) (Chopart, 1999), (iii) initial mapping of root distribution in the soil and exporting the results for other analyses. The user must have spatialized field data beforehand, i.e. the number of root intersections per mesh, and the spatial position of the point of measurement.

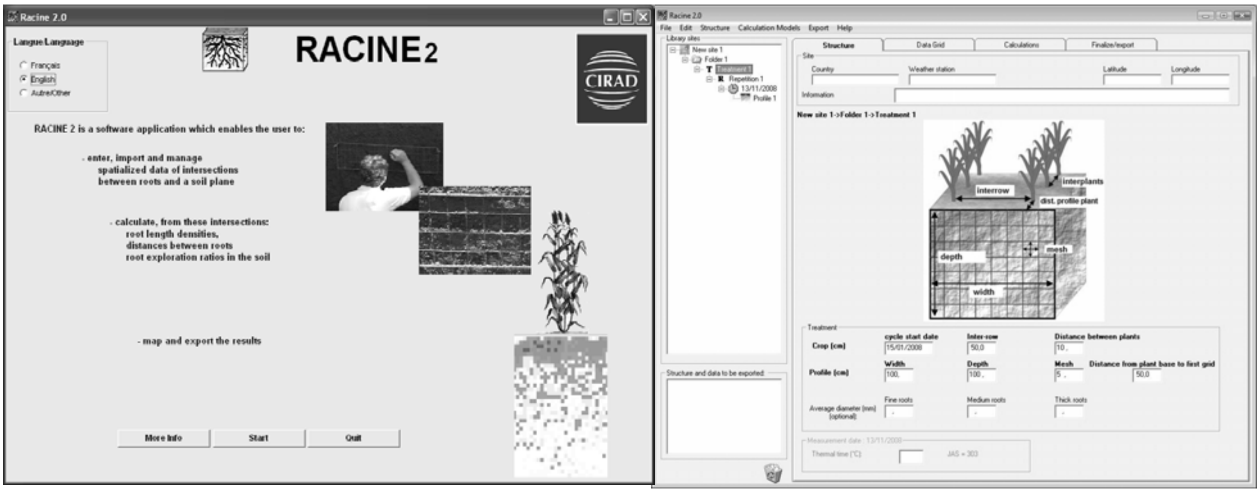

Figure 1. Home page of RACINE2 software, featuring the choice of languages, and management of folders enabling the automatic creation of tables for entering root data.

The first stage (Fig.1) consists in identifying and filling in information for a new structure corresponding to the data to be processed (site, trial, treatment, replication, date). This enables the creation of tables corresponding to the intersection-count cards. Then the user enters the root impact counts made in the field. The calculation algorithms of each of the output parameters are either selected in a tab containing the predefined calculation models, or entered. *RACINE2* thus calculates the root characteristics (RLD, ARD, PRER), mesh per mesh, from the data entries of the number of impacts. The values thus calculated can be synthesized and displayed in map form. The data calculated and the maps are exported to a spreadsheet for stocking other analyses.

This software application is available in English and in French, with support and a user guide (Chopart et al., 2008). The authors will send it free of charge upon request.

RESULTS OBTAINED WITH RACINE2

The results displayed in map form by RACINE2 illustrate the spatial distribution of the roots. Maps of RLD, ARD and PRER (Fig. 2), were obtained from the same folder of impact counts on a sugarcane crop in Reunion Island. They show significant spatial variations of RLD deep down. The PRER, between 0 and 100% of the total soil volume, takes into account the average root distances, the potential distances of displacement of soil elements towards the root, and competition between roots.

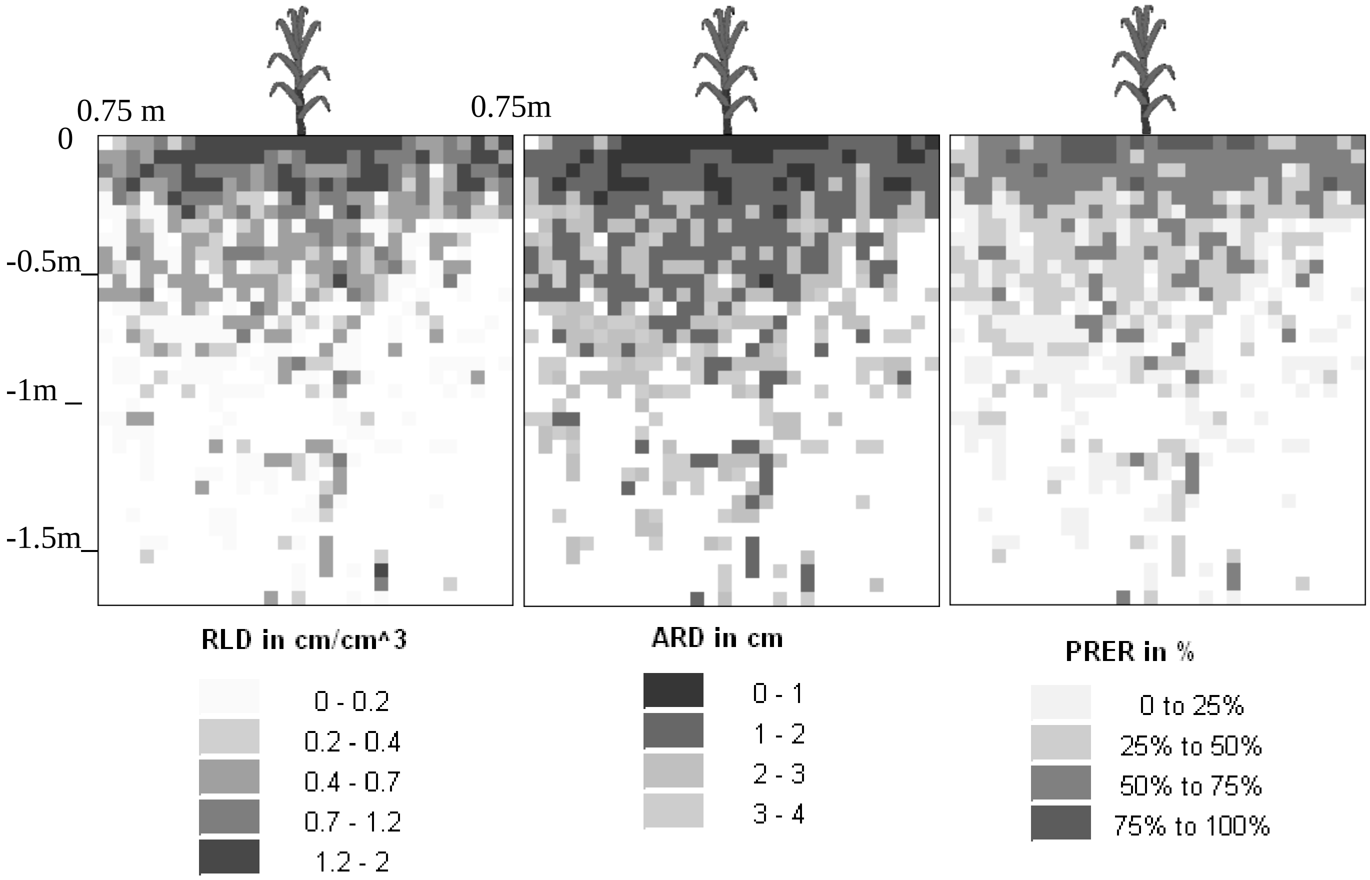

Figure 2. Mapping of root distributions. Profile carried out on sugarcane 220 d after ratoon (Reunion Island). Root length density(RLD), average root distance (ARD) and potential root exploration rate in the soil (PRER)with a 5cm maximum displacement distance of a nutrient towards the root.

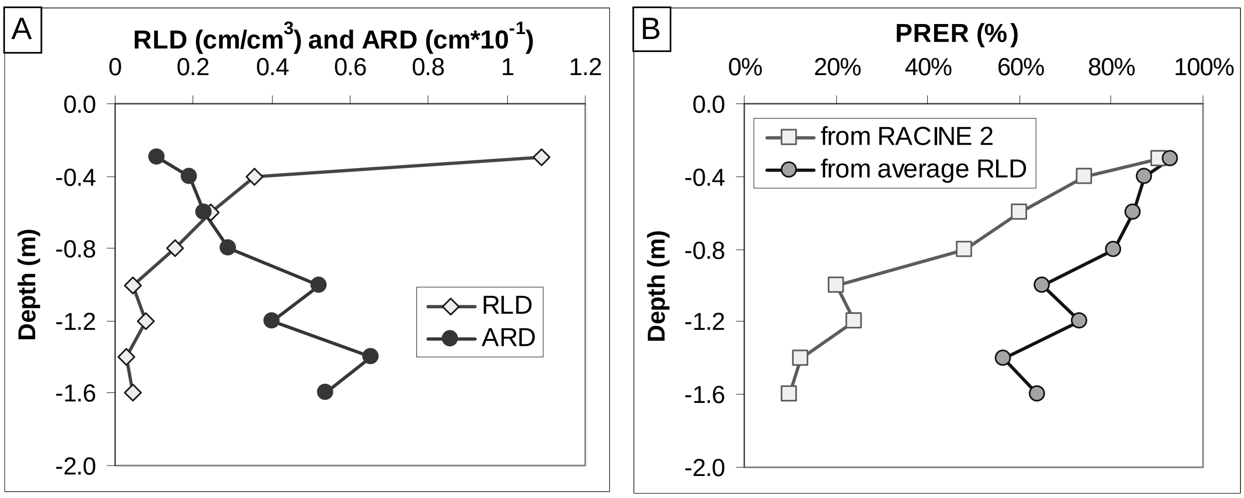

Figure 3. Profiles of sugarcane 220 d after ratoon in Reunion Island. A) root length density (RLD, $cm.cm^{-3}$), average root distances (ARD, $cm.10^{-1}$) and B) potential root exploration rate in the soil (PRER, %), with a 5 cm maximum displacement distance of soil a nutrient towards the root .

With RACINE2, it is of course possible to calculate the root profiles of RLD and ARD according to the depth (Fig. 3a). The root profile of PRER obtained using RACINE2 when retaining 5 cm as the maximum distance that water or a nutrient moves towards the root is quite different deep down to the profile obtained by using the average RLD values, i.e. without taking into account the spatial variability of root distribution. This results in an overestimation of the volume of soil accessible to the roots.

CONCLUSION

The RACINE2 application facilitates the calculation of root parameters (root length density, average root distances, potential root exploration rate) obtained from on-site measurements of root intersection counts using the trench-profile method, rendering the latter method far easier to use. RACINE2 enables a spatialized representation of root parameters to show up the variability of root exploration in the soil according to the latter's characteristics and crop genotype.

Taking into account spatial variability of root system in relation with soil characteristics may be very important for root water and nutrient uptake in field conditions. Consequently this tool can contribute to improved modeling of soil-root and shoot-root interactions.

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