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Multi-model comparison to estimate root growth dynamics of crops from soil moisture time courses and biophysical parameters

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Knowledge of the root distribution and associated root water uptake in the soil profile is essential to estimate the crop water requirements and vulnerability to drought as well as to infer water flux dynamics. Several works aimed at estimating the root architecture from indirect methods (e.g. soil moisture profiles) and from destructive methods (e.g. trench plot). However, no direct method is well established to monitor root growth dynamics
In this study, we test the ability of three models to assess the root depth and the root density profile that are repeatedly measured directly from root imaging along the growing season. In-situ data (soil moisture: 0-50 cm depth, root images: 0-80 cm depth, biomass and plant area index) were collected on irrigated soybean field from May to September 2014 in the vicinity of Toulouse, South West France. Soil moisture profiles and biophysical data were acquired with a 10-min and 15 days time steps, respectively.

Three models are used:
- IRRIMAX is a data-oriented irrigation advice software, based on water balance approach for each soil layer, operating at a daily time step.
- STICS is a widely used crop model that computes water transfer within soil profiles at daily time step. Based on reservoir-type analogy across 1-cm soil layers, it describes also water soil fluxes between four compartments: microporosity, macroporosity, cracks and pebbles.
- HYDRUS 1D is a program that numerically solves the Richards equation for variably saturated water flow. The flow equation incorporates a sink term to account for water uptake by plant roots.

The main result of this study is that root water uptake is mainly driven by the soil moisture redistribution in soil profile. The reservoir-type analogy approach is not adapted to accurately account for deep infiltration associated to fast water fluxes in macropores. The simulation outputs are improved using dual-porosity formalism of Richards model but its calibration remains complicated due to equifinality issues.
The simulated Root Water Uptake (RWU) substantially diverges: STICS simulates most of RWU within the top soil profile while the contribution of deep layers is enhanced with Hydrus 1D. Moreover, it is noticeable that by forcing the root distribution with actual one, obtained by root imaging, the simulations of RWU by STICS better match with the other ones. Yet, the daily time step in STICS remains inadequate to separate fast (water redistribution) and slow (plant water uptake) processes, leading thus to misinterpretation of low frequency signals associated to RWU during rainy events.

The methodology is transposable to any crop system and soil moisture monitoring should also be performed to assess RWU of non-irrigated system and winter crops. In order to allow spatialization of RWU assessments, it appears profitable to use remote infrared observations in addition to few root ones and soil water content maps. This constitutes an appealing way to detect early plant stress and therefore deconvolve RWU by means of SVAT coupled with crop model.