Root distribution and water uptake of contrasted biomass crops in a deep loamy soil

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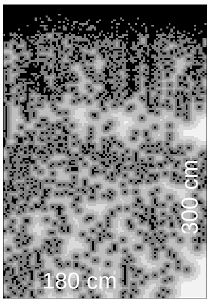
Introduction

Biomass crops dedicated to energy production are expected to provide significant fossil energy substitution and greenhouse gas mitigation. Most studies are related to biomass production or nutrient budget and few of them analyse the impact on water resource (Monti and Zatta, 2009). However, high yield biomass crops are likely to capture more water and affect hydrologic cycle. In this study we compare the rooting systems of six biomass crops and their effect on water capture efficiency.

Materials and methods

- A long-term "Biomass & Environment" experiment was established in 2006 in Northern France in an Ortic Luvisol. Mean annual rainfall is 630 mm and potential evapotranspiration is 731 mm.
- Six biomass crops are evaluated: annual (fiber sorghum SOR and triticale TRI); multi-annual (fescue FES and alfalfa ALF) and perennial (*Miscanthus* x *giganteus* MIS and switchgrass SWI) harvested in October. All are N fertilized except alfalfa.

From the field to the screen



- Soil water content (*SWC*) was measured every year since 2007 in November on soil cores of 30 cm thick down to 150 cm. *SWC* was also measured down to 300 cm in November 2011.
- Vertical root distribution was characterized in 2010 down to 300 cm depth using the trench profile method with a grid of 1.9 x 1.9 cm cell (Tardieu, 1988). The number of roots per cell was counted at least on 20% of the 180 cm width.
- Root length density (*RLD*) of MIS and SWI was determined using an image analysis procedure on washed roots removed from soil monoliths (0-300 cm).
- A relationship was established between *RLD* and the mean number of roots per cell for MIS and SWI and applied to the other species to calculate their *RLD*.
- Plant water uptake is evaluated by the "proportional water capture" defined as $pwc = (Wfc - W) / (Wfc - Wwp)$, where *Wfc* and *Wwp* are the water contents at field capacity and wilting point respectively (Monti and Zatta, 2009). Maximum *pwc* (*mpwc*) was defined for each layer by selecting the highest *pwc* over the 5 years (2007-2011).

Results

Root pattern differed between species. Maximum rooting depth exceeded 250 cm for MIS, SWI and ALF and was less than 200 cm for other species. The proportion of the whole root system (number of colonised cell) include in the 0-150 cm layer was 80% for MIS, 90% for SWI and ALF, 95% for TRI and FES, and 100% for SOR.

Root length density decreased from 2 to 18 cm cm^{-3} in the upper layer (0-30 cm) to less than 0.5 cm cm^{-3} below 90 cm for all species. Differences in *RLD* between species appear in depth (Fig. 1): SOR had the more pronounced *RLD* decrease, followed by TRI and FES and then SWI and ALF. MIS had an original root pattern with the lowest *RLD* in 0-90 cm and the highest in 180-300 cm, in agreement with Neukirchen et al. (1999).

Water consumption is crop dependent: a significant effect of crop on *mpwc* appears in the layer 30-120 cm during 2007-2011 period; *mpwc* was significantly higher for MIS, ALF and FES in 30-60 cm, for ALF and FES in 60-90 cm and for ALF in 90-120 cm (Fig. 2).

In 2011, there was a significant effect of crop on *pwc* in layer 120-210 cm. Besides, *pwc* from 150-210 cm layer represent 10% of total *pwc* from 0-210 cm layer for SOR and TRI, and around 20% for other species.

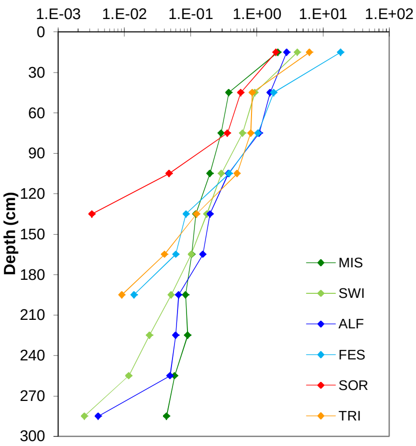


Figure 1: Root length density vs depth

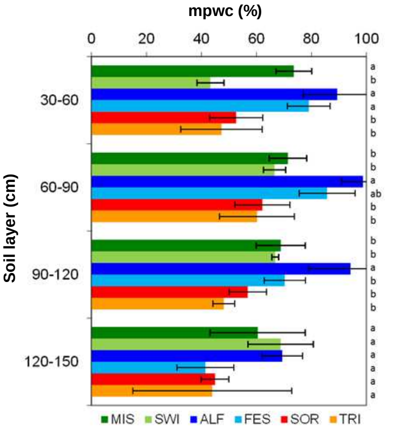


Figure 2: maximum proportional water capture vs depth (2007-2011)

A **relationship between *RLD* and *pwc*** was found in the soil layers between 30 and 210 cm in 2011 (Fig. 3). It was fitted to the model proposed by Monti and Zatta (2009) : $pwc = 1 - e^{(-k * RLD)}$. The differences in *pwc* between crops can be expressed by the resource capture coefficient (*k*). For a given *RLD*, a larger *k* value means a more efficient water capture.

The *k* values ranked as follows: MIS > SWI > TRI. *RLD* from 2010 was not reliable for FES, ALF and SOR in 2011, due to low biomass development. For MIS and SWI, Monti and Zatta (2009) founded lower *k* values, but with different root pattern. In the future, we should confirm hypothesis on root systems and use *SWC* from TDR probes down to 200 cm.

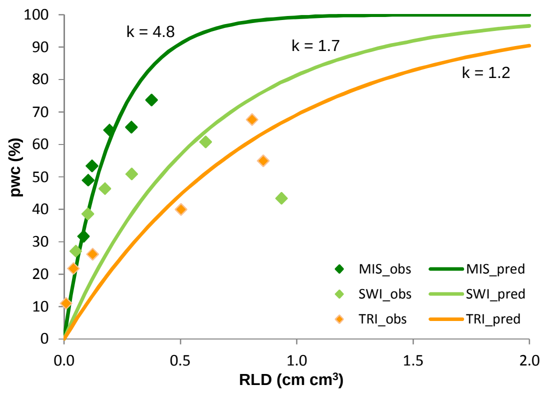


Figure 3: proportional water capture vs root length density (2011, on 30-210 cm)

Conclusions

Our study shows a large variability in rooting patterns along the soil profile between crops. Perennial and multi-annual crops can develop a deep and dense rooting system in this deep loamy soil. Higher *RLD* allows crops to capture more water, but other parameters can influence water capture efficiency and should be taken into account in the future. Aboveground biomass production, phenology, root diameter, C3/C4 characteristics can help explaining actual water uptake. We show that deep water uptake occurs at least down to 210 cm, which represent up to 20% of the total *pwc*. The role of these deep roots is probably more important during drought period. It is likely to impact water drainage and groundwater recharge.

References: Monti and Zatta, 2009. *Agriculture, Ecosystems & Environment* 132: 252-259. ; Neukirchen *et al.*, 1999. *European Journal of Agronomy* 11: 301-309. ; Tardieu, 1988. *Plant and Soil* 107(2): 259-266.

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