Preliminary use of induced polarization measurement to study tree roots growing in earth dikes

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Context and motivations

Roots are recognized as an environmental hazard when growing in hydraulic earth structures, especially dikes. Trees' rooting in earth dikes generates two types of risks: internal erosion due to root development in earth embankments or their foundation, and external erosion (slopes and crest) which is often related to trees uprooting by the effects of currents or wind (Fauchard and Mériaux 2004). The aim of this paper is to elaborate non-destructive prospection methods able to detect and evaluate dangerous tree roots growing in earth dike or dam body.

For now, the electrical prospecting method has been used widely especially for the study of root biomass (Amato et al. 2009). Basically the use of a classical electrical resistivity tomography provides an approximation of the distribution and the volume of the root system. Recently Vanderborgh et al. (2013) proposed an overview of the methods used for studying root zone properties. They pointed out many gaps and challenges of the electrical approach. Among the limits underlined, the main is that the classical electrical tomography may be in some cases an indirect determination of the roots system. A promising approach for mapping more accurately the roots system is to consider the complex resistivity. Related to the classical ERT, this method includes a temporal dimension (Kemna et al. 2000) . Plant and root materials are expected to polarize much stronger and allows obtaining potentially a specific signature of the roots presence. Some studies (Schleifer et al. 2002; Zanetti et al. 2011; Martin 2012) shown a low-frequency response. Moreover Martin (2012) shown that the bioelectrical properties of a tree stem are affected by seasonal variations. These results are fundamentals and should be consider and improve for the root detection.

Thus, thought both soil and biological material implies polarizations effects, we hope to asses in which type of soil and roots we could discriminate the roots from the soil. This work has been initiated during laboratory experimentations and shown that in most cases, the conductivity of buried root samples increased the whole conductivity of the ground among different type of soil (Zanetti et al. 2011).

This study has two main purposes: first we will try to link the polarizations effects with each parameter such as the properties of the roots (type, diameter, function, decay state…), of the soil (type, water content) and seasonal variations of the tree (sap activity). We will focus here on the determination of the weight of soil water content on the measured signal and thus on the ability to detect of the roots. Then in parallel, we develop different methodologies using temporal and frequency instruments. Following the inversion of the data we hope to compare from Cole-Cole parameters the both approach and to conclude about the ability to upscale it on field.

Results from laboratory experiments

We used for this experiment a representative type of soil of mostly dikes composition. The geoelectrical measurements were performed at the soil surface in plastics tanks containers. The tank number 1 is a control containing only the soil while in the tank number 2 is disposed a root at about 6 cm in depth. First the medium were saturated on water. The measurements were repeated each day to study the evolution of the signal with the decrease of water content of the soil.

It seems that the ability to detect the roots even including polarization effects is highly related to water content of the soil. The resistivity seems not affected by the presence of the roots whatever the water content. We observed a decrease of the chargeability over time with the drying of medium in both tanks. Nevertheless we noticed that the ratio of the chargeability in the tank with the buried roots on the tank without root tends to be higher as 1 when the medium is drying.

Results from field experiments

We conducted the field experiment with the same parameters used in laboratory. The positions of the roots were determined previously during the tree planting. In Fig. 1 below, the root system is composed of one single primary roots of 22 mm diameter at about 20 cm depth.

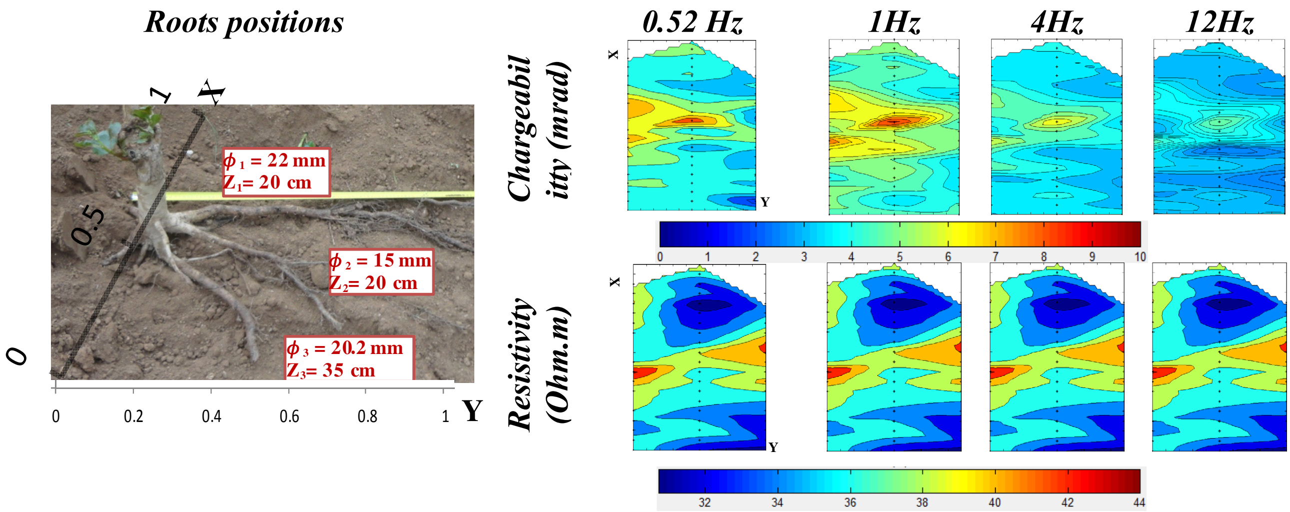

Fig. 1: Mapping of the departure of a poplar primary horizontal root from the trunk; prospect area x =[0,1] m , y =[0,0.2] m, "Wenner" configuration with inter-electrode distance A = 15 cm.

Here we observed a particular case with a correlation both between electrical resistivity and chargeability and the theoretical positions of the roots. While the roots 2 and 3 seems respectively too small and deep for this inter-electrode distance (A = 15 cm), the root 1 may be identified as an anomaly of resistivity and chargeability (45 Ωm, 10 mrad at 1 Hz) on the surrounding soil (30 Ωm). Moreover, the roots seems appears much more clearly at low frequency (< 1 Hz).

At this stage of the study, we shown that the information provides by the polarization physic seems relevant to localize roots in the soil. Unfortunately the signal at very low frequency is very noisy and depends on a lot of external parameters. Therefore efforts should be done for offers a better understanding and conduct prospection on real conditions.

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