Tree root mapping with ground penetrating radar

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ABSTRACT

In this paper, the application of ground penetrating radar (GPR) for the mapping of near surface tree roots is demonstrated. GPR enables tree roots to be mapped in a non-destructive and cost-effective manner and is therefore a useful prospecting tool in a variety of diverse study fields, including geohydrology, ecology and civil engineering. Case study examples are presented of how GPR can play a role in detecting and quantifying subsurface biomass and also how GPR can be used to discriminate between subsurface roots and man-made utilities.

Key words: Ground penetrating radar, tree roots, utilities

INTRODUCTION

While utility detection is a well documented and possibly the most common GPR application [e.g., Lester and Bernold, 2007; Thomas et al., 2006], the use of GPR to map tree roots seems to be somewhat of a novelty. In recent years, however, researchers have expressed some interest in using non-destructive technologies such as GPR to assist in subsurface tree biomass estimations [Butnor et al., 2003]. In light of this growing interest, two independent, but similar near-surface case studies are presented here, in which GPR is applied to the detection and mapping of tree roots.

The first problem scenario is of a geohydrological/ecological nature: The structure of tree roots are generally influenced by the prevailing groundwater conditions: In cases where abundant groundwater is present within the near surface, a tree may develop a prominent vertical tap root system and deeper extending lateral roots in order to exploit such water. In dryer conditions, where little or no groundwater occurs at depth, a tree is likely to develop predominantly shallow lateral roots to exploit near-surface moisture [Callaway et al., 2003]. In the latter case, the tree may also compete with grasses and other vegetation for limited water resources. Knowledge of the presence or absence of different types of roots can therefore contribute to improving the understanding of these interactions. GPR is well suited to mapping the presence and extent of lateral tree roots in the first few meters of the near-surface. For the mapping of vertical tap roots one would need to resort to the use of borehole radar (Butnor and Johnsen, 2006).

The second problem scenario is one often encountered in civil engineering / urban areas, where subsurface utilities such as water and drain pipes and electricity and telecommunication cables often occur in close proximity to growing trees with laterally extending root systems. Over time, these developing root systems may cause significant damage to utilities and to other types of infrastructure such as road surfaces and building foundations. GPR can be used as a monitoring tool in cases where tree root damage is suspected or anticipated.

CASE STUDY 1 - KRUGER NATIONAL PARK

Figure 1 shows a Google Earth image of an area alongside the Sabie River, a few kilometres west of the Shingwedzi Camp in the Kruger National Park, South Africa. Two areas of interest outlined in red on the image, are located south and north of the river, respectively. GPR trial surveys were acquired on the surface in these areas and included data acquired in two perpendicular directions. Data acquisition was done using a *Rock Noggin* system (*Sensors & Software Inc*., Canada) with a 250 MHz antenna.
The site south of the river contains a number of relatively tall *Mopani* trees with heights ranging from approximately 12 m to 30 m. In contrast, the *Mopani* trees north of the river are relatively small, with heights ranging between 1.8 m and 5.5 m. The height difference is thought to be related to contrasting groundwater scenarios south and north of the river. The larger trees of the wetter southern site are expected to have deeper roots with greater lateral extent compared to their counterparts north of the river. These inferences were confirmed by the comparing output radargrams. Overall, the data quality was not very good and the root responses generally did not have a sharp contrast with the background and were therefore difficult to pick.

Figure 2 shows a comparison between typical radargrams from the respective sites.

On Shingwedzi South, Profile 15 (SS-15), inferred tree root reflections can be observed (marked with yellow arrows) at the following locations:
$x \approx 7$ m, $z \approx 1.9$ m;
$x \approx 24$ m, $z \approx 3.6$ m;
$x \approx 31$ m, $z \approx 2$ m;
$x \approx 32$ m, $z \approx 3.7$ m;
$x \approx 43$ m, $z \approx 1$ m;
$x \approx 48$ m, $z \approx 2$ m;
and several shallow root reflections in the very near surface ($z \approx 0$-1 m

Tree root responses are difficult to identify across the whole of the Shingwedzi North (SN) survey grid. On SN-17, for example, one can again identify a few shallow root reflections, between $x \approx 18$ and $x \approx 45$ m, and mostly in the upper 0-1 m of the subsurface.

The Shingwedzi GPR results indicated that, as expected, the trees north of the Sabie River may have less extensive and shallower lateral roots compared to the bigger trees on the southern side of the river. It should be emphasized that surface GPR is not capable of detecting vertically orientated roots; also, any roots that lie deeper than the effective probing depth of the GPR system (approximately 4 m at the Shingwedzi sites) cannot be detected.

CASE STUDY 2 – CSIR CAMPUS, PRETORIA

The survey site is a grassed area located on the campus of the Council for Scientific and Industrial Research (CSIR) in Pretoria, South Africa. A *Burkea Africana* (Wild Syringa) tree and an *Ochna Pulchra* (Lekkerbreek) tree are located in close proximity to a number of known subsurface utilities. Both tree types typically have lateral and fairly shallow root systems. A small 12 m x 12 m survey area, approximately the same size as the trees' combined canopy, was defined. This area is traversed by two separate subsurface electricity lines as well as two separate subsurface water pipe lines. The approximate location of these utilities, which was obtained from utility maps of the area, is shown in Figure 3. Details regarding the probable geometry and construction of these utilities follow:

- Fresh water pipe line – a 160 mm diameter pipe constructed of asbestos;
- Garden water pipe line – a 110 mm diameter pipe constructed of PVC;
- High-voltage power line – a near-solid metallic cable constructed of multiple copper conductors inside a lead outer; total cable thickness is ~ 50 mm.

A total of 51 GPR profiles were acquired along two perpendicular directions: 26 W-E and 25 S-N profiles. Data acquisition was done using a *Rock Noggin* system (*Sensors & Software Inc*.) with a 500 MHz antenna. A profile length and spacing of 12 m and 0.5 m, respectively, were used throughout the survey.

In Figure 4 a typical S-N profile is compared with a typical W-E profile. The inferred utility responses are marked in the same colours as in the map in Figure 3. Some inferred roots are marked in yellow. As expected, the known utilities generally produce classic hyperbolic responses when crossed perpendicularly (S-N) and appear as linear reflectors when tracked approximately along their strike (W-E). The tree root anomalies are generally less pronounced than the utility responses - and are also less predictable. When roots are crossed more or less perpendicularly, the responses are also hyperbolic; however, the fact that roots don't generally maintain a linear extent results in many distorted reflections that are difficult to interpret. In order to separate utilities from tree roots and to obtain accurate plan maps and/or depth sections of tree roots and utility distributions a detailed 3D survey and processing approach is required.

CONCLUSIONS

Individual lateral tree roots that approach a linear geometry, can be detected with GPR provided the property contrast with the background is sufficient. The GPR profile direction should ideally be perpendicular to the strike of the root. However, the variable geometry and unpredictable nature of tree roots often make them more difficult to pick out on individual 2D radargrams. Utilities are much easier GPR targets due to their typically distinct property contrast with the surrounding soil and their fairly predictable or known linear geometry and depth. Where discrimination between utilities and tree roots is required a detailed 3D survey approach is recommended.

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FIGURES

Figure 1: Google image of the Shingwedzi survey area.

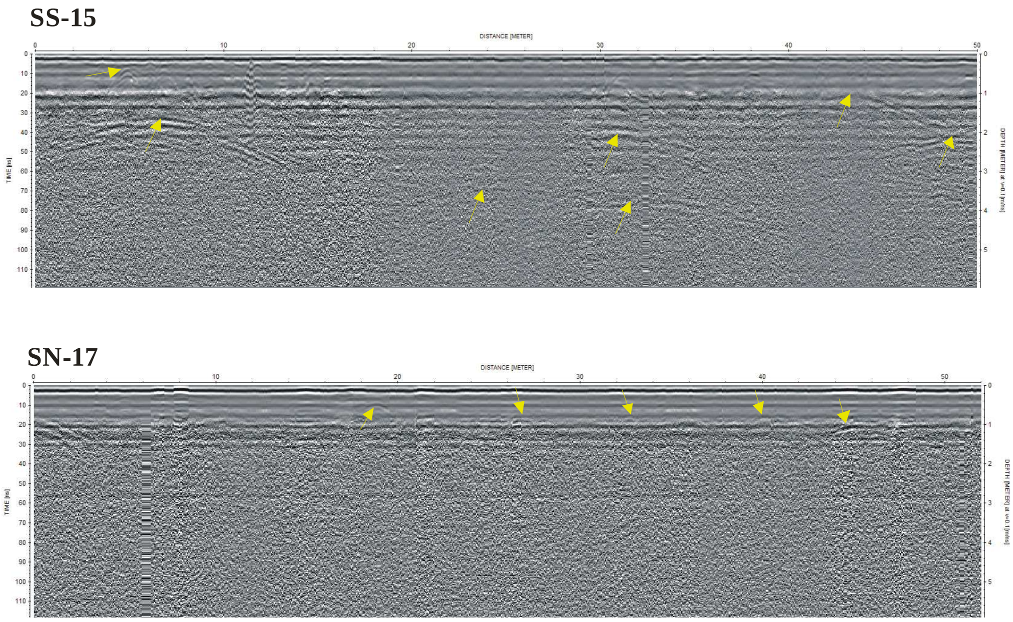


Figure 2: Comparison of typical Shingwedzi South and North radargrams.

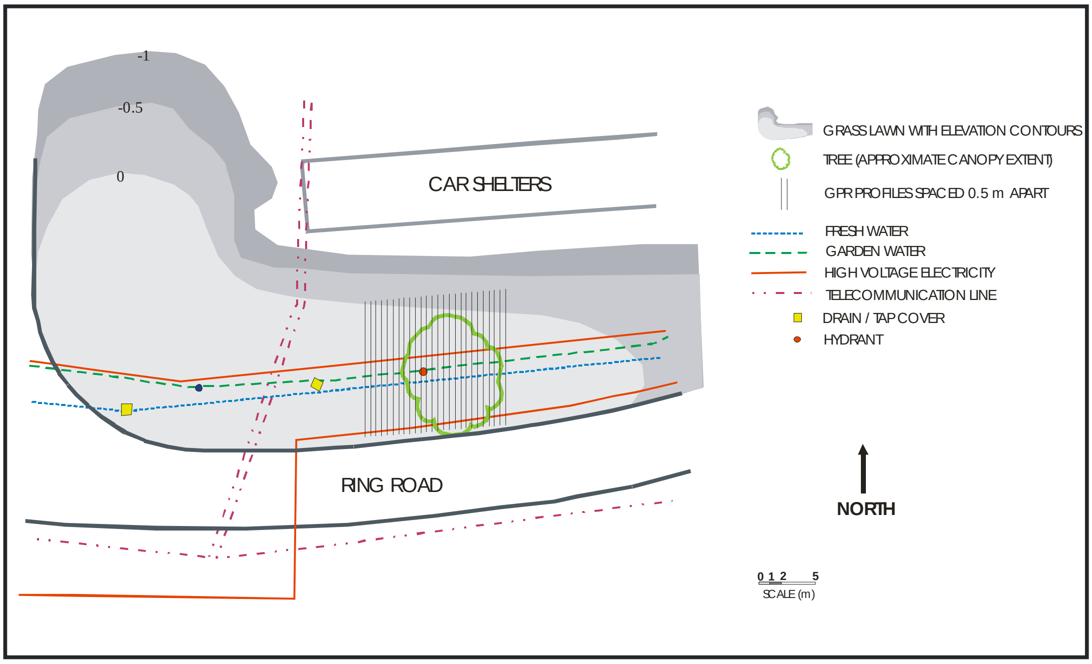
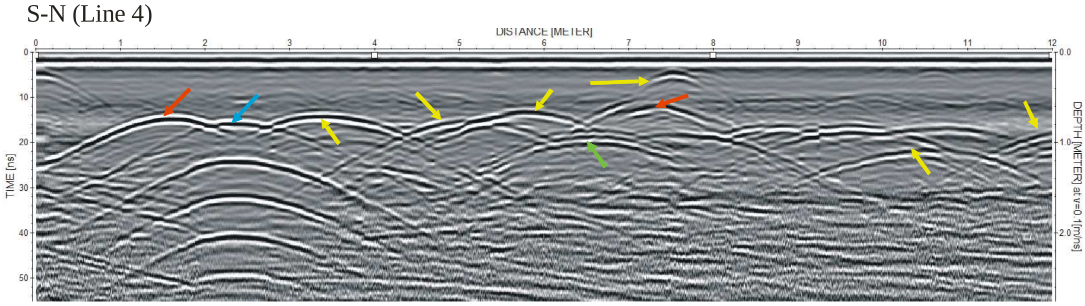


Figure 3: Site map of GPR study area on CSIR campus, Pretoria.

S-N (Line 4)



W-E (Line 5)

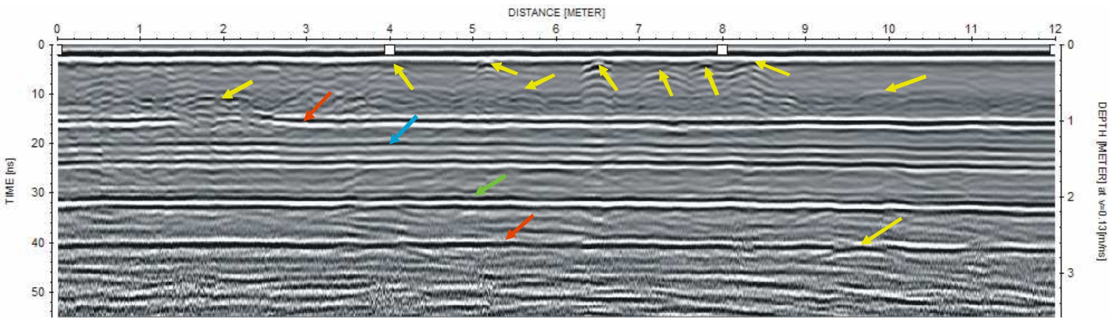


Figure 4: Selected radargrams from the CSIR site.