Using ground penetrating radar for defining groundwater vulnerability due to the impact of agricultural activity

Marjana Zajc & Janko Urbanc

Geološki zavod Slovenije, Dimičeva ul. 14, 1000 Ljubljana, Slovenija; marjana.zajc@geo-zs.si, janko.urbanc@geo-zs.si

5.000.000.000 _ 5.0
5. SLOVENSKI GEOLOŠKI KONGRES
DO 5 MILIJARD LET Z DRUŽBO 5.0

GeoZS Geološki zavod Slovenije

SLOVENSKO GEOLOŠKO DRUŠTVO

Introduction

Agriculture is a major source of groundwater pollution in Slovenia (MOP, 2015), therefore groundwater vulnerability assessment is important for a sustainable food production. Two main parameters used for this assessment are the thickness of the top soil and the depth to the groundwater table (Ravbar, 2007). Both are determined either with different devices (piezometers, wells, boreholes) or by excavations, however these only give information on specific points in the field. Due to the heterogeneity of the hydrogeological conditions in the environment, especially in karst areas (Ravbar, 2007), they do not represent the overall situation. Consequently, the vulnerability assessment can be either over- or underestimated. By using the ground penetrating radar (GPR) method, we can investigate the subsurface in a non-invasive way and track both soil thickness as well as water table depth in a continuous way across the field (Kirsch, 2009). By conducting a comprehensive study of selected agricultural areas in Western Slovenia we can contribute to a more precise assessment of groundwater vulnerability and a more sustainable food production.

The project was selected for funding by the Ministry of Education, Science and Sport within the public call for the Promotion of researchers at the beginning of their career 2.0. The project is a collaboration between the Geological Survey of Slovenia and the Vitrum Laser company.

Method

GPR is a geophysical method based on the principles of electromagnetic waves emitted from the transmitting antenna into the subsurface and reflected from the boundaries between rock and sediment layers and other objects with different electromagnetic properties. Due to its efficiency and non-destructive nature, the use of the GPR method has been increasing rapidly in geological studies, e.g. in the analysis of faults and fractures, in the detection of karstic structures and cavities, in the mapping of sediments as well as in the watertable depth determination (Blindow et al., 2007). It enables easy and rapid data collection, while the results provide subsurface information also in areas where no outcrops or boreholes are present (Neal, 2004). Lower antenna frequencies allow for greater penetration depths while higher antenna frequencies provide results with higher resolution (Jol, 2009). For the research conducted within this project, GPR equipment from Mala with three different antenna frequencies are being used, namely 250, 500 and 800 MHz (Fig. 1).

Figure 1: GPR equipment used. Left – 250, 500 and 800 MHz antennas; Right – GPR cart with 250 MHz antenna, operating unit and monitor.

Preliminary results

In order to test the GPR method, measurements were carried out in agricultural areas where different horizons have been previously defined by excavations and soil profiling in the Goriška Brda region (Glavan, 2011). Figure 2 shows the results of a part of the GPR profile BRDA 6, recorded with two different antennas (250 and 500 MHz) between two rows of a vineyard (Fig. 3). The soil profile of this area is described in Table 1. The GPR results correlate well with the soil profile characteristics. All three horizons can be seen in profiles recorded with both the 250 MHz and the 500 MHz antenna, with the latter providing a much higher resolution image of the subsurface. In addition, GPR results also show a fourth horizon below the depth of 1 m, which was not reached with soil profile excavations. Significant changes in the thickness of the horizons II and III can be observed along the profile, indicating a heterogeneous setting with laterally changing hydrogeological conditions.

Table 1: Characteristics of the soil profile in the BRDA 6 area (after Glavan, 2011) and corresponding horizon labels in the GPR profile.

Depth	Horizon	Lower boundary form	Lower boundary distinctness	GPR horizon
0 – 23 cm	Ap	Smooth	Clear (2 – 6 cm wide)	I
23 – 55 cm	A2	Smooth	Gradual (5 – 15 cm wide)	II
55 + cm	CA	/	/	III

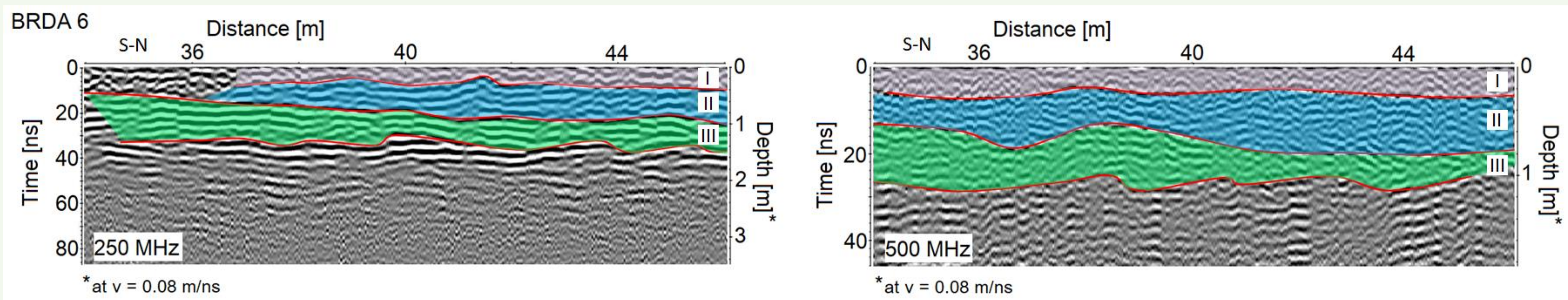

Figure 2: Part of the GPR profile BRDA 6 measured with two antenna frequencies (left - 250 MHZ; right – 500 MHz). In both cases three horizons (I – violet, II – blue and III – green) are marked.

Figure 3: Location of GPR profile BRDA 6.

As the GPR results can be highly dependent on the soil moisture content, the same profiles were also recorded in a dry season and after a rain event. Figure 4 shows a comparison of profile BRDA 8 recorded with the 250 MHz antenna in dry (left) and wet conditions (right) between two rows in a vineyard (Fig. 5). Zones with higher attenuation of GPR signals (red frames) are more pronounced in the wet conditions, which could indicate that these are areas with higher clay content and therefore have a better ability of retaining water in comparison to more coarse-grained soils with faster water drainage. Consequently, such areas do not require as much irrigation and fertilisation as other parts of agricultural fields.

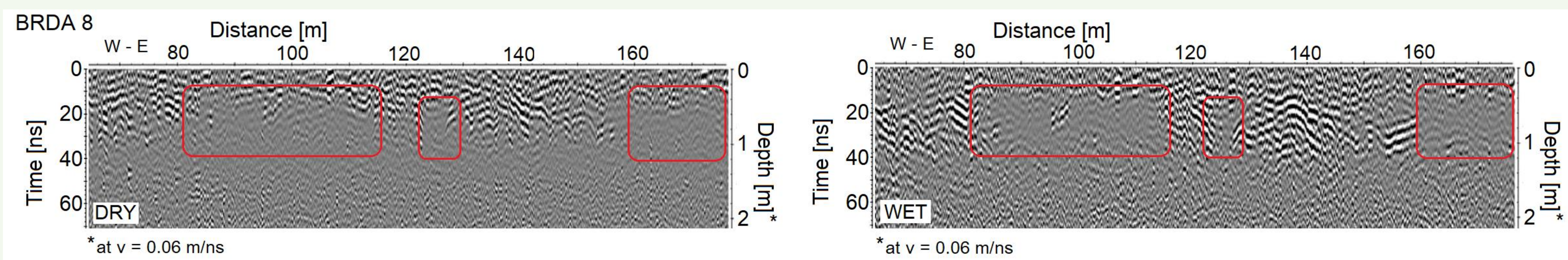

Figure 4: Part of the GPR profile BRDA 8 recorded in dry (left) and wet (right) conditions. Red frames indicate areas with high signal attenuation.

Figure 5: Location of GPR profile BRDA 8.

Discussion and conclusions

Based on GPR results obtained in the Goriška Brda region (W Slovenia) it is evident that heterogeneous settings allow for hydrogeological conditions in agricultural fields to change rapidly. Point information about the subsurface characteristics (e.g. from soil profiling, boreholes and piezometers) is therefore insufficient for a detailed groundwater vulnerability assessment. GPR results can provide continuous information about the changing thickness of different horizons within agricultural fields as well as additional information about the lateral changes in soil types and moisture content. By conducting a comprehensive study of selected agricultural areas we can contribute to a more precise assessment of groundwater vulnerability and a more sustainable food production.

References

- Blindow, N., Eisenburger, D., Illich, B., Petzold, H., Richer, T. 2007. Ground Penetrating Radar. In: Knödel, K. (ed.), Lange, G. (ed.), Voigt, H.-J (ed.). Environmental Geology. Handbook of Field Methods and Case Studies. Berlin, Heidelberg, New York: Springer: 283-335
- Glavan , M. 2011. Vpliv spremenjene rabe zemljišč na količino in kakovost vode v reki Reki v Goriških Brdih in reki Dragonji : doktorska disertacija = Impact of changed land use on the quantity and quality of water in the river Reka in Goriška Brda and the river Dragonja : doctoral dissertation. Univerza v Ljubljani, Ljubljana.
- Jol, H. M. (ed). 2009. Ground Penetrating Radar: Theory and Applications. Amsterdam, Netherlands, Oxford, UK: Elsevier Science,
- Kirsch, R. (ed). 2009. Groundwater Geophysics: A tool for Hydrogeology. 2nd edition. Berlin, Heidelberg, Springer-Verlag Publication.
- Ministrstvo za okolje in prostor Republike Slovenije. 2015: Načrt upravljanja voda 2016-2021.
- Neal, A. 2004. Ground-penetrating radar and its use in sedimentology: principles, problems and progress. Earth-Science Reviews, 66, 3-4: 261-330
- Ravbar, N. 2007. Vulnerability and risk mapping for the protection of karst waters in Slovenia. Application of the catchment of the Podstenjšek springs. Doktorska disertacija, Univerza v Novi Gorici. Nova Gorica.

REPUBLIC OF SLOVENIA
MINISTRY OF EDUCATION, SCIENCE AND SPORT

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

VITRUM LASER
3D Visualization Technologies