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Mapping of Agricultural Subsurface Drainage Systems Using Time and Frequency Domain Ground Penetrating Radars

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Agricultural subsurface drainage systems are installed in naturally poorly drained soils and areas with a rising water table to drain the excess water, eradicate soil salinization issues and increase crop yields. Globally, some of the most productive regions are a result of these artificial drainage practices. The installation of drainage systems provides many agronomic, economic, and environmental benefits. However, inevitably, they act as shortened pathways for the transport of undesired substances (nutrients, pesticides, and pathogens) through the soil profile promoting their increased leaching and offsite release to the surface water bodies. This drainage water cause potential eutrophication risk to the aquatic ecosystem. For example, the hypoxic zone in the Gulf of Mexico and harmful algal blooms in Lake Erie can be linked to the nitrogen and phosphorus losses from the Midwest USA agricultural areas. Hence, the knowledge of the location of these installations is essential for hydrological modelling and to plan effective edge-of-field mitigation strategies such as constructed wetlands, saturated buffer zones, denitrifying bioreactors, and phosphate filters. Moreover, their location is also important either in order to initiate repairs or retrofit a new drainage system to the existing one. Nevertheless, subsurface drainage installations are often poorly documented and this information is inaccurate or unavailable, inducing the need for extensive mapping campaigns. The conventional methods for drainage mapping involve tile probing and trenching equipment. While the use of tile probes provide only localized and discrete measurements, employing trenching with heavy machinery can be exceedingly invasive and carry a risk of severing the drainage pipes necessitating costly repairs. Non-destructive soil and crop sensors might provide a rapid and effective alternative solution. Previous studies show ground penetrating radar (GPR) to be especially successful; owing to its superior resolution over other near-surface geophysical methods. In this study, we tested the use of a stepped-frequency continuous wave (SFCW) 3D-GPR (GeoScope Mk IV 3D-Radar with DXG1820 antenna array) at study sites in Denmark and a time-domain GPR (Noggin 250 MHz SmartCart) at study sites in the Midwest USA to map the buried drainage pipes. The 3D-GPR mounted in a motorized survey configuration and mobilized behind an all-terrain vehicle proved certainly advantageous to get full coverage of the farm field area and provided the flexibility of adjusting the frequency bandwidth depending on the desired resolution and penetration depth (PD). Two different approaches were tested to estimate the PD and comparisons were made with electrical conductivity data measured using an electromagnetic induction instrument. With the impulse GPR, data collected along limited parallel transects spaced a few meters apart, spiral and serpentine segments incorporated into random survey lines proved sufficient when used adjacently with unmanned aerial vehicle imagery. In general, a better success can be expected when the average soil electrical conductivity is less than 20 mS m^{-1} and it is a recommendation to perform the GPR surveys preferably in a direction perpendicular to the expected drain line orientation when the water table is at/below the drainage pipes' depth.