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Health monitoring of an ancient tree using ground penetrating radar – investigation of the tree root system and soil interaction

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The sensibility towards environmental issues along with the attention on preserving natural heritage, especially ancient trees and rare plants, has greatly increased, and the management and the control of the forestall heritage and the floral system has become accordingly a high-priority objective to achieve. One of the main factors of tree decay which originally gained public attention is the presence of unknown pathogens carried along by the wind, which can lead to epidemic phenomena and often to a quick death of entire forests. In such an emergency situation, two main approaches can be followed, namely, i) active measures (i.e. the avoidance of any contact between the pathogenic spores and the trees by using bio-security measures) and ii) passive measures (i.e. the application of policies for the control and the management of the forestall heritage aimed at identifying the early-stage symptoms of the disease). Since the latest approach is based on the monitoring of living trees, invasive methods of health assessment like cutting off branches or incremental coring are increasingly discouraged, and non-destructive evaluation proves to be the only option to undertake. The applications of non-destructive testing (NDT) techniques in forestry sciences are often self-standing and not integrated with one another. This is often due to a lack of knowledge from the NDT users towards the physics and the bio-chemical processes which mainly govern the life cycle of trees and plants. Such an issue is emphasized by the evident complexity of the plant and trunk systems themselves. Notwithstanding this, the ground-penetrating radar (GPR) technique has proved to be one of the most effective, due to its high versatility, rapidity in collecting data and the provision of reliable results at relatively limited costs. The use of GPR can provide invaluable information about the effective tree trunk assessment and appraisals, tree roots mapping, soil interaction with tree and plants. In addition, the use of simulation can be a supporting tool for the development of a clear understanding of the decay processes in trees.
In this study, a demonstration of the GPR potential in the health monitoring of an ancient tree has been given. The main objectives of the research were to provide an effective mapping of the tree roots as well as reliable simulation scenarios representing a variety of possible internal defects in terms of shape and formation. To these purposes, the soil around a 100-years old fir tree, with a trunk circumference of 3.40 m and an average radius of 0.55 m, was investigated. Nine radial scans, 0.30 m spaced each to one another, were carried out all around the tree circumference starting from 0.50 m the outer surface of the bark. A ground-coupled multi-frequency GPR system equipped with 600 MHz and 1600 MHz central frequency antennas was used for testing purposes. In order to reach the maximum penetration depth of the root system, only the 600 MHz frequency was considered for data processing purposes. After the application of a dedicated signal processing scheme, it was possible to produce a tomographic map of amplitudes covering a swept circle with an outer radius of 3.45 m and an inner radius of 1.05 m up to a maximum depth of 1.56 m. By using a set of specially developed algorithms it was possible to extract signal amplitude information reliably related to the position of the tree roots under the soil.
In addition to the above objective, finite-difference time-domain (FDTD) simulations of the electromagnetic field propagation through the cross section of a trunk were carried out. To this purpose, the numerical simulator package gprMax 2D was used. The freeware tool E2GPR aided the design of the gprMax models and their distributed execution on multicore machines. The dimensions and the dielectric properties of the simulated trunk were consistent with the investigated fir tree (actual data collected). Furthermore, a variety of defects representing cavities created due to decay was simulated. The results from the simulations demonstrated significant potential for the interpretation of complex decay phenomena within the trunk as well as for mapping and comparison of the actual field data.

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