Electromagnetic Simulation of Norway Spruce and Scots Pine for Root Volume Estimation via SAR Tomography

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Abstract— Remote Sensing systems currently use optical or Synthetic Aperture Radar (SAR) images obtained by satellites, aircrafts or drones. None of them has subsoil penetration capability as provided by Ground Penetrating Radars, GPRs. However, GPRs operate at ground level or at several meters above ground, presenting a very low survey coverage capability. Subsoil penetration together with high survey coverage capability are important features for measuring the forest and its belowground biomass. In this work, a methodology is being developed to survey a volume of 4 hectares with a depth of 10 m within 20 minutes drone flight at 120 m altitude by using SAR tomography [1]. This article reports the first electromagnetic simulation results by illuminating trees with different root structures using a circular flight pattern. Two types of trees were considered: the Norway Spruce and the Scots Pine [2]. The simulation was carried out by assuming the trunks to have the shape of a cylinder of 10 m height and 0.2 m diameter for both tree types. Two different root structures were considered: the roots of the Norway Spruce were simulated as a cylinder of 0.5 m height and 5 m diameter and the one of the Scots Pine, with a height of 5 m and 5 m diameter. Additionally, a simulation was carried out with the trunk only and without any root volume. A dielectric constant of 4 for the soil and 8 for the trunk and roots was considered. The needles of the trees were not considered. A circular flight trajectory was simulated and the data were processed to generate focused SAR images, which were analyzed by drawing profiles of the radar cross section (RCS) that cut the area where the structures of interest are located. The trunk of the Scots Pine represented a RCS, which was 5 dB higher than the RCS of the trunk without any root volume. The Norway Spruce represented a RCS which was 0.5 dB lower than the Scots Pine. The simulations showed a clear dependence between tree RCS and its root volume by using circular flight patterns. Moreover, the helical flight pattern, described in [1], will provide the resolution in the vertical direction and allow a direct estimation of the root volume. The advantage of this methodology is the direct estimation of the total tree-root biomass, which is currently not technically or economically feasible to estimate by any other methodology. Future developments show a possible area coverage of 400 hectares by a drone flight height of 1000 m within 1-hour drone flight time.

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