

ABSTRACT

This study developed a non-destructive method for estimating topsoil thickness using Stepped Frequency Continuous Wave (SFCW) radar technology. Topsoil is the top layer of soil that determines land productivity and quality, so information on its thickness is important for precision agriculture and conservation. Conventional methods such as manual excavation are invasive, time-consuming, and impractical on a large scale. The experiment was conducted in three stages: numerical simulation, laboratory testing, and field testing. In the laboratory stage, artificial soil media with aluminum reflectors were used as a reference for the lower soil boundary. In the field stage, measurements were taken on plantation land with two surface conditions: weed-covered and weed-free. Data acquisition used A-scan for the time domain and B-scan for spatial interpretation, with validation results compared to actual thickness. Results showed that the SFCW radar system could detect the topsoil boundary with up to 99.0% accuracy under laboratory conditions, with a standard deviation of <0.19 cm from 250 repeated measurements. In field measurements, accuracy dropped sharply to 2.0% under weed-covered conditions, but improved to 89.0% after the surface was cleaned, with a standard deviation of <0.31 cm. B-scan analysis confirmed that reflection quality and spatial accuracy are significantly influenced by surface conditions. SFCW radar has high potential as a non-invasive instrument for estimating topsoil thickness. For more reliable field applications, signal processing techniques and surface interference mitigation are required. This research provides a quantitative basis for the development of radar-based soil monitoring systems in the fields of precision agriculture and land conservation.

Keywords: Topsoil thickness, SFCW radar, dielectric permittivity, ground-penetrating radar (GPR), electromagnetic reflection.