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Estimation of the damage caused by different wood extraction systems to soil applying traditional and innovative methodologies.

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Soil disturbances are one of the main damage associated with forestry operation. Tree harvesting, skidding and transportation carried out by heavy machinery may results in substantial, long-lasting, and sometimes irreversible soil damage (reduced porosity, water infiltration, soil aeration, and soil erosion), thus decreasing tree growth and seedling establishment and development. The soil damage extent and severity caused by skidding and forwarding are function of soil condition, harvesting system and machine characteristics. Soil compaction and rutting, the main negative consequences of forest logging, are usually investigated by means of time-consuming and costing methods. New and more accurate methods have been developed to capture and investigate the spatial distribution of soil disturbance on the base of 3D ground photogrammetric reconstruction. In this context, the overall objective of this study was to investigate innovative and traditional methods for evaluating rutting and its relation with soil compaction caused by a loaded forwarder and skidder. Different methods were applied for determining soil disturbance: i) manual measurement and 3D soil modelling by portable laser scanner and close-range photogrammetry analysis were used to determine rutting and soil displacement (rut depth, bulges height and rut volume); ii) cone penetration resistance, soil bulk density and soil porosity measurements were used for determining soil compaction. Our findings show a relationship between soil compaction (i.e. cone penetration resistance) and rutting (i.e. total reduction of soil volume) in low moisture soil condition. The shortest data acquisition was observed during the portable laser scanning, while in accuracy rutting estimation was higher in close-range photogrammetry. The comparison of photogrammetric and manually-measured profiles confirmed that Structure For Motion photogrammetry can be an accurate instrument for the modeling of ground morphology and the analysis of soil disturbance after forest logging. Furthermore, the results contrasted the effect of different harvesting systems and terrain conditions on soil disturbance, highlighting that the skidder is more impacting for soil than the forwarder considering the same wood volume extracted.