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Changes in some mechanical properties of a loamy soil under the influence of mechanized forest exploitation in a beech forest of central Belgium

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Abstract

Modification of some soil mechanical properties (penetration resistance and consolidation pressure) induced by vehicle compaction during mechanized forest exploitation was studied in an acid and loamy leached forest soil of the loessic belt of central Belgium. In situ penetration tests and laboratory *Bishop–Wesley cell* tests were undertaken for the two main soil horizons of a beech high-forest, i.e. the eluvial E horizon (5–30 cm depth) and the underlying clay-enriched B_t horizon (30–60 cm depth). Both undisturbed and wheel-rutted soil areas were studied (E and B_t horizons vs. E_g and B_{tg} horizons). Results show that: The experimental overconsolidation pressure of the eluvial reference horizon (E) is about 50 kPa higher than the value calculated from soil overburden pressure; this probably results from suction action during dry periods. The clay-enriched reference horizon (B_t) shows the same trends. In wheel-rutted areas, seven years after logging operations, the E_g horizon memorizes only 14.5% of the wheel induced stress due to forest machinery. In the compacted B_{tg} horizon, the experimental overconsolidation pressure represents 96% of the exerted theoretical stresses due to harvesting actions. The good recording of the exerted stresses, after seven years, can be explained by: (1) The B_{tg} depth which keeps it from seasonal variations i.e.

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from desiccation–moistening or freeze–thaw cycling; (2) amorphous and free iron accumulation inducing a "glue" effect of the B_{tg} soil matrix, which could stabilize the soil structure and prevent recovery to initial conditions. These results provide clear evidence that on loessic materials, soil compaction due to logging operations leads to modifications in both physical (bulk density, total porosity) and mechanical (penetration resistance and consolidation pressure) soil properties.

Keywords: Soil compaction; Soil degradation; Rutted forest soils; Overconsolidation pressure

1. Introduction

In forest ecosystems, the increase in size, power and weight of forest machinery is one of the main causes of soil degradation (soil compaction and related effects) [1,2], the soil being subjected to severe stresses due to mechanical forces exerted by tractor tyres and skidding. Results of soil compaction include the increase in bulk density, the reduction in macroporosity, and, consequently, reduced soil aeration and water holding capacity [3–6]. This results in a poor rooting, inducing lower uptake of nutrients and water, and possibly a decrease in tree growth [2,7,8] or an increase in sensitivity of radial growth [9]. Moreover, soil compaction and root damage increase the risks for windthrow and infection by root pathogens [10,11].

Soil susceptibility to compaction is mainly determined by particle-size composition, organic matter content and biological activity level. Biological activity is particularly important for soil structural regeneration. Therefore, more attention should be given to degradation in fine-textured and acid forest soils, with low levels of biological activity [12]. These soils are known to be very sensitive to compaction especially where natural soil remediation is very low or even non-existent [3,13,14].

In the loessic belt of central Belgium, the silvicultural management of loamy soils developed under beech stands frequently results in severe soil physical degradation, which causes surface waterlogging (*gleization*) in the areas compacted by wheel-ruts [5,15]. In such conditions, natural forest regeneration is impeded and costly soil improvements may be necessary before planting trees. Moreover, soil compaction due to machine traffic is often referred to as an important aggravating factor in beech decline [16].

In spite of their importance for a sustainable forest management, few analytical data have been published in regard to the degradation of soil physical properties under the influence of repeated wheeled traffic during logging operations and, to our knowledge, changes in soil mechanical properties have been appraised in a forest environment only recently [37,38]. The aim of this study is therefore to use mechanical laboratory tests (*Bishop–Wesley* cell tests) to determine to what extent the mechanical properties and mainly compressibility of a loamy soil developed under a beech forest are affected by logging operations. Previous results had shown that a "cementation" effect as defined by Biarez et al. [17] was detectable in the mid-depth horizon of the wheel-rutted areas [6].