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Relative bulk density as a measure of compaction and its influence on tree height

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Abstract: Soil compaction often limits conifer regeneration on sites degraded by landings and roads, but inadequate understanding of the relationship between compaction and tree growth could lead to inappropriate soil conservation and rehabilitation efforts. We tested liquid and plastic limits, oxidizable organic matter, total carbon, particle size distribution, and iron and aluminum oxides on soil samples collected from five forest experiments in interior British Columbia. These data were used to estimate soil maximum bulk density (MBD) and relative bulk density (RBD); our objective was to relate RBD to tree growth. Height of interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Bessin) Franco) was limited when RBD was >0.72. For lodgepole pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.) and hybrid white spruce (*Picea glauca* (Moench) Voss × *Picea engelmannii* Parry ex Engelm.), RBDs of 0.60–0.68 corresponded to maximum height, whereas RBDs of 0.78–0.87 appeared to limit height growth. The presence of surface organic material mitigated compaction and was often associated with lower RBD. Our results illustrate the usefulness of RBD to assess compaction and suggest that soil rehabilitation should be considered on disturbed sites where soil RBD is >0.80.

Résumé : La compaction du sol nuit souvent à la régénération des conifères sur les sites dégradés par les jetées et les chemins mais une compréhension inadéquate de la relation entre la compaction et la croissance des arbres pourrait se traduire par des mesures inappropriées de réhabilitation et de conservation du sol. Nous avons testé les limites liquide et plastique, la matière organique oxydable, le carbon total, la distribution de la dimension des particules et les oxydes de iron et d'aluminium sur des échantillons de sol prélevés dans cinq expériences établies en forêt dans la partie intérieure de la Colombie-Britannique. Ces données ont été utilisées pour estimer la densité apparente maximale et la densité apparente relative (DAR). Notre objectif consistait à relier la DAR à la croissance des arbres. La hauteur du douglas de Menzies bleu (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) était réduite lorsque la DAR était > 0,72. Dans le cas du pin tordu latifolié (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.) et de l'épinette blanche hybride (*Picea glauca* (Moench) Voss × *Picea engelmannii* Parry ex Engelm.), une DAR de 0,60 à 0,68 correspondait à la hauteur maximale tandis qu'une DAR de 0,78 à 0,87 semblait limiter la croissance en hauteur. La présence de matière organique en surface atténuait l'effet de la compaction et était souvent associée à une DAR plus faible. Nos résultats illustrent l'utilité de la DAR pour évaluer la compaction et indiquent que la réhabilitation du sol devrait être envisagée sur les sites perturbés où la DAR est > 0,80.

[Traduit par la Rédaction]

Introduction

The use of heavy machinery in forest management often leads to soil disturbance and compaction, which in turn affect ecosystem stability and site productivity (Froehlich 1979; Wronski and Murphy 1994; Kuan et al. 2007). Soil disturbance and compaction can be particularly severe on permanent and temporary access areas, such as forest roads and landings. These areas may be unproductive unless soil rehabilitation is carried out. Trees growing on compacted soil are generally characterized by reduced root elongation (Whalley et al. 1995) and, sometimes, by reduced height growth (Greacen and Sands 1980; Ares et al. 2007; Bulmer et al. 2007), but predictability varies. The variation in tree growth responses reported in different studies could have been caused by selection of compaction indicators that were not always successful in describing the relationship between soil compaction and tree growth or by the fact that compaction treatments did not reach growth-limiting levels in some studies. Because soil rehabilitation practices are expensive to apply, a compaction evaluation method to better understand soil compaction effects on tree growth is needed.

Soil bulk density (BD) has been traditionally used as the most common measure of soil compaction, but establishment of growth-limiting BD thresholds is not straightforward. Any threshold value of BD depends on soil properties (e.g., texture, quantity and quality of organic matter, and particle density), site characteristics (e.g., microclimate), and the criteria used to evaluate when growth is affected. A review by Daddow and Warrington (1983) showed that

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