# FOREST PRODUCTIVITY AS A FUNCTION OF ROOT GROWTH OPPORTUNITY

by

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(ABSTRACT)

Compaction caused by certain intensive forest management practices can reduce tree growth, but the causes of growth reduction are usually complex interactions between soil properties and tree species. We used a 7 by 7 factorial greenhouse experiment to create a matrix of bulk density ($\rho_b$) and volumetric water content ($\theta_v$) to determine soil compaction effects on seedling growth of: (i) ponderosa pine (Pinus ponderosa Dougl. ex Laws) grown on Dome and Cohasset soils from California; (ii) shortleaf pine (Pinus echinata) on a Clarksville soil from Missouri; and (iii) loblolly pine (Pinus taeda) on an Argent soil from South Carolina. We also characterized soil physical properties and determined compaction effects on soil strength, air/water balance and least limiting water range (LLWR) for each of the soils. Optimum water content for compaction varied from 19% (Argent) to 34% (Cohasset). Compactive effort curves varied for the four soils; maximum $\rho_b$ were 1.33, 1.52, 1.58 and 1.65 Mg $m^{-3}$ for the Cohasset, Dome, Clarksville, and Argent soils, respectively. Compression indices ranged from 0.33 to 0.38. In general, soil strength increased linearly with a $\theta_v$ decrease at the higher $\rho_b$ levels, but the effect varied with each soil type. Cohasset, with the lowest $\rho_b$, had the highest soil strength (3.5 MPa), while strengths exceeding 2.0 MPa were not found for the Argent soil. Compaction affected the soil water retention curves and associated air/water balance parameters for all soils, particularly the Cohasset and Dome soils. Aeration porosity became limiting at $\rho_b$ of 1.13, 1.42, 1.44 and 1.55 for the Cohasset, Dome, Clarksville and Argent soils respectively. The LLWR was lowest for the Dome and Argent soils (0.13 $cm^3$ $cm^{-3}$) and in some cases increased with compaction. Models of root growth opportunity were developed using multiple regression. The general model of root length

density (RLD) = $b_0 + b_1 \theta_v + b_2 \rho_b + b_3 \theta_v^2$ described rooting response for the Clarksville-shortleaf and Argent-loblolly soil-species combinations ($p = 0.005$). However, the root response of ponderosa pine on Cohasset was linear and pine roots in the Dome soil responded to an interaction between $\theta_v$ and $\rho_b$. No model adequately described oak seedling growth as a function of $\rho_b$ and $\theta_v$. High soil strength at low water contents and low aeration porosity at high water contents limited root growth. Shoot mass of seedlings growing within the least limiting water range (LLWR) was greater than those growing outside the range for all soil-species combinations except the Argent-loblolly pine ($p = 0.05$). The loblolly pines had greater shoot mass at volumetric water contents above the upper LLWR limits (aeration limiting). The LLWR is a promising method for integrating compaction's influence on soil properties and thus root growth potential since single factors did not appear to adequately explain each soil's compressibility. Furthermore, response surface models of RLD as a function of $\theta_v$ and $\rho_b$ in conjunction with the LLWR and seasonal site water data have potential for determining compaction- induced soil limitations for tree growth, but need to be calibrated for both soil and species.

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## TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF TABLES