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Effects of Logging-Induced Soil Compaction on the Abundance and Characteristics of Fine Roots and Mycorrhizal Associations in Forest Soils and their Recovery

Lisa Gasser[1], Maximilian Behringer[1], Marcus Froemel[2], Douglas Godbold[1,3], Julian Grünberg[4], Christoph Haas[5], Armin Hofbauer[6], Klaus Katzensteiner[1], Barbara Kitzler[6], Martin Kühmaier[4], Gerhard Markart[7], Gertraud Meissl[8], Nikolaus Nemestothy[5], Hans Sandén[1], Christian Scheidl[2], Alexandra Wieshaider[9], and Boris Rewald[3]

[1]University of Natural Resources and Life Sciences (BOKU) Vienna, Institute of Forest Ecology, Vienna, Austria
[2]University of Natural Resources and Life Sciences (BOKU) Vienna, Institute of Mountain Risk Engineering, Vienna, Austria
[3]Mendel University in Brno, Faculty of Forestry and Wood Technology, Brno, Czech Republic
[4]University of Natural Resources and Life Sciences (BOKU) Vienna, Institute of Forest Engineering, Vienna, Austria
[5]Austrian Research Centre for Forests, Institute of Forest Engineering, Traunkirchen, Austria
[6]Austrian Research Centre for Forests, Department of Forest Ecology and Soil, Vienna, Austria
[7]Austrian Research Centre for Forests, Department of Natural Hazards, Innsbruck, Austria
[8]University of Innsbruck, Department of Geography, Innsbruck, Austria
[9]Austrian Federal Forests, Purkersdorf, Austria

Soil compaction in forests, often a result of logging activities, poses a significant threat to soil functioning and ecosystem services. Root systems and their symbiotic relationships with mycorrhizae are particularly affected. Given the vital role that sustainably managed forest ecosystems play for climate change resilience and mitigation, understanding the effects of soil compaction on belowground functioning is critical. To address knowledge gaps on the interactions between soil compaction, root growth, and mycorrhizal associations under real-world conditions, it is essential to conduct comparative studies on different harvesting methods. Detailed analyses are required to better understand the spatiotemporal effects of logging on soil as a rooting space.

To investigate the complex relationships, we implemented different harvesting methods (harvester-forwarder with or without bogie tracks, cable-yarding with motor-manual-felling) and a control treatment between skidding trails in a beech-dominated forest in Lower Austria during the winter of 2022/23. In addition, we sampled ~20-year-old skidding trails (harvester-forwarder) to assess soil recovery.

Using a replicated transect approach across the skidding trails, we studied spatially explicit effects on standing fine root biomass to a depth of ~45 cm in a before-after control-impact design. To allow for upscaling, each transect included areas directly impacted by logging (i.e. skidding trails, cable-yarding corridors) and areas potentially indirectly affected (i.e. between the ruts, bulge area etc.). We conducted comprehensive assessments of fine root biomass depth distribution, and key

traits such as anatomy, morphology and fine root nutrient content, as well as mycorrhization rates.

The data indicate a significant negative influence of both recent and historical timber harvesting on standing root biomass, revealing altered patterns of root distribution with notable differences between and within transects. Our results suggest that different harvesting methods result in very different levels of soil compaction, leading to contrasting effects on fine root traits such as a reduction of absorptive surface area relative to biomass in compacted soil.

The persistence of negative effects on the old skidding trails highlights the long-lasting impact on root systems and their mycorrhizal symbionts, and thus key ecosystem functions. This emphasizes the importance of conserving forest soils and the need to identify and implement management strategies to minimize soil compaction and promote recovery. These efforts are vital for ensuring the sustainable provision of ecosystem services by the 'hidden half' of forests.