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Quantifying below-ground forest carbon, including carbon fluxes via litterfall and roots across European forests

Mathias Neumann (1), Hubert Hasenauer (1), Adam Moreno (2), Lars Vesterdal (3), Anne Thimonier (4), Sue Benham (5), Liisa Ukonmaanaho (6), Lars Lundin (7), Leena Finer (8), Yasuhiro Hirano (9), Douglas Godbold (10), Ainars Lupikis (11), Radek Novotny (12), and Arne Verstraeten (13)

(1) Institute of Silviculture, Department of Forest- and Soil Sciences, University of Natural Resources and Life Science, Wien, Austria, (2) NASA Ames Research Center, Moffett Field, USA, (3) Department of Geosciences and Natural Resource Management, University of Copenhagen, Copenhagen, Denmark, (4) Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf, Switzerland , (5) Forest Research, Farnham, UK, (6) Natural Resources Institute Finland, Helsinki, Finland, (7) Swedish University of Agricultural Sciences, Uppsala, Sweden, (8) Natural Resources Institute Finland, Joensuu, Finland, (9) Graduate School of Environmental Studies, Nagoya University, Nagoya, Japan, (10) Institute of Forest Ecology, Department of Forest- and Soil Sciences, University of Natural Resources and Life Sciences, Wien, Austria, (11) Latvian State Forest Research Institute, Salaspils, Latvia, (12) Forestry and Game Management Research Institute, Jiloviste, Czech Republic, (13) Research Institute for Nature and Forest, Brussels, Belgium

European forests, covering one third of the land surface in Europe, have recently sequestered more than 700 million tonnes CO_2 every year. Belowground biomass accounts for about 7%, forest floor for 9% and soil for 54% of the total European forest carbon (C) stocks. Thus, more than two thirds of forest C are stored below-ground or at the soil surface. This underlines the importance of soil pools for C sequestration in forests worldwide. Soil and forest floor C pools originate from the interaction of C input by litterfall and roots and C output by decomposition of the incorporated matter. Biomass functions in combination with forest inventory data allow estimating the carbon stocks of coarse roots usually defined by a minimum diameter of 2 mm. Apart from that, most countries have no systematic reporting on soil C input, since data on litterfall and root turnover are difficult and expensive to record. In this study we collate consistent information on coarse roots, above-ground litterfall and fine root production, to enhance our knowledge on quantifying C input into forest soils.
A gap-filled map based on harmonized forest inventory data from 13 countries provides coarse root carbon information across Europe. Our results suggest that the carbon stocks in coarse roots are highest in temperate central-European forests, most likely due to high stocking and favorable climatic conditions. With data from 237 research plots we can show that coarse root C (about 14 t C ha-1) exceeds C stored in fine roots (about 1.8 t C ha-1, equal 13% of coarse root C). Ignoring fine roots within carbon accounting thus neglects a substantial amount of below-ground carbon. We also quantify C flux into soil pools using data from more than 400 research plots across Europe (320 plots provide aboveground litterfall and 85 plots fine root production). The analyzed data indicates that in European forests C input by litterfall (224 g C m-2 year-1) exceeds belowground C input (130 g C m-2 year-1) assuming 50% carbon content in fine roots. Broadleaves seem to exhibit a higher fine root production (270 g m-2 year-1) and also a higher litterfall (514 g m-2 year-1) than conifers with a fine root production of 256 g m-2 year-1 and a litterfall of 373 g m-2 year-1.
Our analysis shows strong evidence that the C input from above-ground litterfall represents about 34% and fine roots about 21% of the total forest Net Primary Production. It also shows that reliable, large scale C fluxes and pool information should be combined with decomposition models to better quantify the forest's carbon sequestration and resource availability for an emerging bio-based economy.