Effects of intensive biomass harvesting on soil organic carbon and nutrients

Published results and experimental data on effects of intensive forest biomass harvesting on soil organic carbon (SOC) and nutrient concentrations and stocks show that intensified harvesting tends to lead to reduced concentrations and stocks of soil nutrients and SOC in Nordic forest soils, compared with conventional harvesting. Potentially, this has implications for site productivity in the next rotation as well as for the ability of forest soil to sequester carbon.

In conventional stem-only harvesting (SOH), branches, tops and stumps are left in the forests. As a large part of the nutrients in trees are in the needles and branches, removing these during whole-tree harvesting (WTH, Fig. 1) for bioenergy will reduce nutrient supply to the soil. In the long term, this might increase the risk for nutrient imbalance and reduced forest production. In addition, there may be a reduction in SOC in the forest floor. However, field experiments have found partly contrasting results for soil chemistry. There is a need for more knowledge about which factors determine the observed differences, and of how variation in these factors affects long-term site sustainability.

Fig. 1. Whole-tree harvesting at Gaupen, Norway. Photo: Kjersti Holt Hanssen.

We evaluated the effects of forest biomass harvesting on stocks of organic carbon and nutrients in Nordic and UK forest soils, by creating a database of experiments comparing SOH and WTH treatments and carrying out a meta-analysis to quantify and test effects of intensified forest biomass harvesting on SOC and soil nutrients on a broader regional scale.

Our results generally suggest greater reductions in nutrient concentrations, SOC and total nitrogen (TN) after WTH compared with SOH in Nordic temperate and boreal forest soils (Fig. 2), consistent with results obtained on a worldwide scale. Effects were greater in the forest floor than in the mineral soil, and greater in the topsoil than the subsoil, where few effects were detected. Spruce- and pine-dominated stands had mostly comparable negative relative responses in the forest floor to intensified harvesting. There appeared to be greater effects of WTH relative to SOH in a warmer climate. The differences between effects of different harvest types in the forest floor and topsoil were generally reduced with time but were likely to last for several decades.

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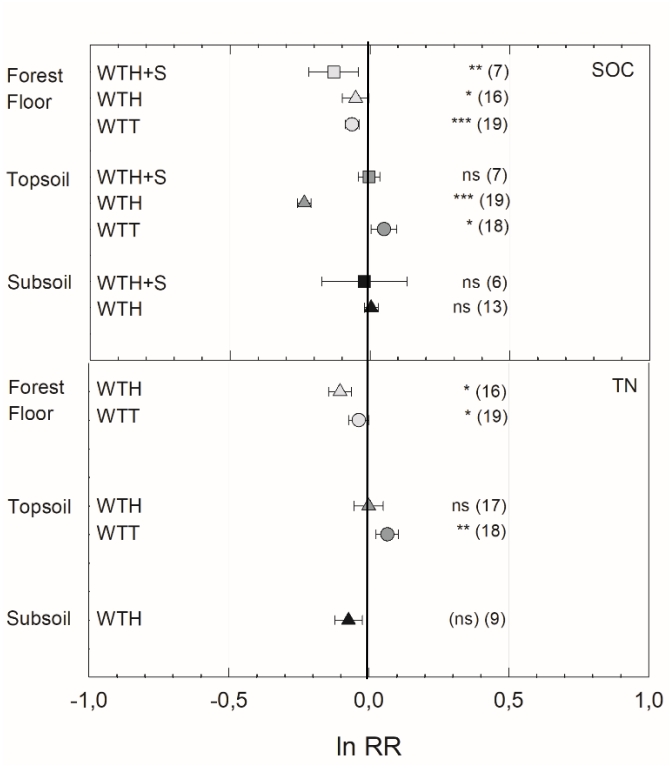

*Fig. 2. Log-transformed response ratios, ln(RR), of soil organic carbon (SOC) and soil total nitrogen (TN) in the forest floor, topsoil, and subsoil layers following whole tree thinning (WTT), whole tree harvesting (WTH), and WTH with stump removal (WTH+S) as compared to conventional stem-only thinning or harvesting (SOH). RR is the concentration or stock of an element in the soil of the WTH treatment divided with the same parameter in the SOH treatment. Negative values indicate that the intensified treatment has a larger effect than SOH. Enough observations for the WTH+S treatment were only available for SOC. Significance levels are indicated as ns (P≥0.10), (ns) (P=0.05-0.10), * (P<0.05), ** (P<0.01), *** (P<0.001) and number of observations included is shown in parentheses. From Clarke et al. (2021).*

Increased loss of nutrients and SOC after intensified harvesting could lead to reduced productivity in the next forest rotation as well as lower carbon sequestration in the forest soil, but it remains uncertain how the impact is linked to individual nutrients. Compensatory fertilization, for example with wood ash combined with nitrogen fertilizer, could be used to counteract nutrient loss, but might also lead to increased decomposition and loss of carbon. Although carbon sequestration in soil at stand level is likely to be reduced after intensified harvesting, long-term carbon sequestration in forest soil might not be reduced as long as other forest stands grow and continue to store carbon.

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Reference

Clarke N, Kiær LP, Kjønaas OJ, Bárcena TG, Vesterdal L, Stupak I, Finér L, Jacobson S, Armolaitis K, Lazdina D, Stefánsdóttir HM, Sigurdsson BD, Effects of intensive biomass harvesting on forest soils in the Nordic countries and the UK: A meta-analysis. Forest Ecology and Management DOI: https://doi.org/10.1016/j.foreco.2020.118877 (2021).