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Alarming loss of soil carbon stores due to intensive forestry measures in the Boreal forest zone in Finland

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Abstract

The effects of modern intensive forestry measures on soil organic carbon (SOC) stores in both mineral soil podsols and peatland histosols have been investigated in Finland with novel methods applying the chronosequence approach (inventories at adjacent natural vs. treated sites, re-investigation of formerly inventoried sampling points).

Regarding peatlands, the results extrapolated to a nationwide figure, indicate an annual loss of 9 Tg C yr^{-1} (33 Tg CO_2 yr^{-1}), which is more than fourfold the magnitude reported for the IPCC for Finland. The new results from mineral soil podsols indicate that soil tilling in connection with clearlogging will persistently diminish the soil SOC stock on average by 10-15 %, with a more profound effect in the middle and northern boreal forest zones. This observation contradicts the figures of steadily increasing mineral soil forest SOC reported for the IPCC from Finland. The 'official' estimate is actually based on a SOC model, which does not take into account the change of original soil C store due to tilling.

The results seriously contradict the alleged climate neutrality of the intensive forestry practices currently conducted in Finland.

Keywords: Podsols, histosols, forest soils, SOC, soil tilling, ditch-draining, Finland

Introduction, scope and main objectives

Timber growth in the Finnish forests has been steadily increasing due to intensive forestry practices, including soil treatments, applied during the past decades throughout the country. Soil treatments has extensively affected both podsols (predominant conifer forest soil type on dry mineral grounds) as well as histosols (peat soils on moist and waterlogged sites). Some 30 % of forest podsols, or 58,000 sq km, have been variously tilled after clearcutting throughout the country since the 1970s. About 60,000 sq km of peatlands have been ditch-drained for forestry; thus, more than 80 % of the original peatlands in the southern and middle parts of the country have been affected.

Regular forest resource inventories were started in Finland already in the 1920s, and the ongoing inventories provide detailed data on the timber stocks and flows, published annually by the Natural Resources Institute, Finland (https://www.luke.fi/en/natural-resources/forest/forest-resources-and-forest-planning/). However, the forest soil organic carbon (SOC) pools are much less precisely accounted for, even though these are considerably larger than those of the tree stock.

I have studied the effect of ditch-draining on the carbon balance of peatlands with my colleagues (Pitkänen et al. 2012, 2013, Simola et al. 2012), and recently the effects of podsol tilling on mineral soil forests (Simola, submitted manuscript 2017). Our results indicate considerably larger forestry-related SOC losses from both peat and podsol soils than those officially reported for the IPCC for the Finnish LULUCF sector (e.g.:

http://mmm.fi/documents/1410837/1867349/Information_on_LULUCF_actions_FINLAND_final_1.pdf/89fc7c83-ebe9-444a-8deb-ca0c3c08ff8b).

Methodology

Analyses of ditch draining effects on peat soil SOC

We studied SOC inventory changes on forestry-drained peatlands by re-sampling the peat stratum in 2009 at the precise locations of quantitative peat mass analyses conducted as part of peatland transect surveys during the 1980s. Altogether 37 sites were precisely located by GPS and the entire peat profile of these were cored quantitatively (Simola et al. 2012). The old and new profiles were correlated mainly by their ignition residue stratigraphies; at each site we determined a reference level, identifiable in both profiles, and calculated the cumulative dry mass and C inventories above it.
Using an alternative approach, we analyzed, by similar quantitative methods, adjacent pairwise peat profiles collected from both sides of a ditch demarcating the natural (undrained) and the in the 1970s drained half of an eccentric raised bog in East Finland (Pitkänen et al. 2013).
At all the study sites, we also investigated the apparent dynamics of growth and degradation of the surface peat strata by pine seedling root collar analyses (for further details, see Pitkänen et al 2012).

Mineral soil (podsol) studies

Effects of forest floor tilling on the soil carbon content were studied at sites where an old natural forest stand is bordered by a younger stand regenerated by clearcutting. Altogether 93 study sites were investigated across the entire Boreal forest zone in Finland (latitude range 59° 57' – 68° 25' N, elevation range 2—390 m a.s.l.). The study sites were selected from aerial photographs so as to represent the various mineral soil treatments customarily applied in Finnish forestry (ploughing, mounding, disc trenching, patch scarification, or no soil preparation). Most of the sites were located at the margins of nature protection areas; in northern Lapland some strip-felling sites were also included. At each site, 20 topsoil cores were taken from both the old forest stand and the adjacent regeneration stand with a 10-cm^2 sampler, down to the uppermost mineral layer, and their organic matter (OM) contents were determined as loss-on-ignition.

Results

Peat profile analyses

Comparison of the re-sampled profiles, with a total of 37 locations, revealed broad variation, from slight increase to marked decrease of SOC; on average the 2009 results indicate a loss of 7.4 (SE ± 2.5) kg m^{-2} dry peat mass when compared with the 1980s values. Expressed on an annual basis, the results indicate an average net loss of 150 g C m−2 year−1 from the soil of drained forestry peatlands in the central parts of Finland. The C balance appeared not to correlate with site fertility (fertility classes according to original vegetation type), nor with post-drainage timber growth. A similar magnitude of C loss was observed for the partially drained mire: on average 131 +/- 28 g C m^{-2} yr^{-1} (mean +/- SE).

Podsol profile SOC investigation

The total material included 93 sites. In order to exclude the short-term OM increase due to logging residue, the main conclusions are drawn from those 75 sites that were aged over ten years since the logging: 48 sites with soil tilling (age range 11—40 years) and 27 non-tilled sites (16—100 years). In nearly 80 % of the tilled sites, the soil OM content had decreased in comparison with the adjacent old forests; non-significant OM increase was observed in a few of the tilled sites due to paludification. As for clearcuts without soil treatment, an average loss of only 300 g OM m^{-2}, or 3.9 %, was observed; the difference between tilling and non-tilling is statistically significant (RMANOVA).

The average OM decrease for all the >10-year tilled sites is 1 260 g OM m^{-2}, corresponding to about 15 % decline from the old-forest level. The effect of tilling on SOC decline is more profound in the northern parts of the country (Middle and Northern Boreal forest zones).

Discussion

Our published carbon inventory studies of forestry-drained peatlands (Simola et al. 2012, Pitkänen et al. 2013), summarized here, point to a large error in the Finnish GHG accounting. We conclude that the carbon emissions from forestry-drained peatlands in reality would be some 9 Tg C a^{-1} (33 Tg CO_2 a^{-1}), or about 3.5 times higher than the figures currently reported for that land-use category (Ministry on Agriculture and Forestry 2014).

Our root collar study (Pitkänen et al. 2012), conducted at the same sites as the present investigation, demonstrates that apparent C accumulation usually takes place at the soil surface, even when the net C balance of the entire peat deposit is negative.

Regarding the podsol forest soils, the big losses from tilled sites as compared with the non-tilled ones points to a fundamental change in soil quality and persistent decline of soil carbon stocks caused by tilling. Based on the current forest floor tilling rate in Finland (1200 km^2 annually), a rough estimate of CO_2 emissions in the order of 2.8 Tg $a^{-1,}$ and a total of some about 130 Tg CO_2 emitted since the 1960s (about 58 000 km^2 of forests tilled so far), can be concluded.

The observed persistent 15% decline of soil carbon stocks, due to the routinely performed soil tilling in connection of clearlogging, clearly contradicts the figures of steadily increasing mineral soil forest SOC reported for the IPCC from Finland. The 'official' estimate, claiming climate neutrality or even climate benefits for the intensive forestry currently practiced in Finland, is actually based on a SOC model (YASSO07; see Tuomi et al 2011), which does not take into account the change of original soil C store due to tilling.

Conclusions

The results of recent podsol and peat SOC balance change studies, summarized above and presented and discussed in more detail in the referred publications, seriously contradict the alleged climate neutrality of the intensive forestry practices currently conducted in Finland.

References

Ministry of Agriculture and Forestry 2014. Information on LULUCF actions, Finland. http://mmm.fi/documents/1410837/1867349/Information_on_LULUCF_actions_FINLAND_final_1.pdf/89fc7c83-ebe9-444a-8deb-ca0c3c08ff8b

Pitkänen, A., Simola, H. & Turunen, J. 2012. Dynamics of organic matter accumulation and decomposition in the surface soil of forestry-drained peatland sites in Finland. Forest Ecology and Management 284, 100–106. doi.org/10.1016/j.foreco.2012.07.040

Pitkänen, A., Turunen, J., Tahvanainen, T. & Simola, H. 2013. Carbon storage change on a partially forestry-drained boreal mire determined through peat column inventories. Boreal Environment Research 18: 223-234.

Simola, H., Pitkänen, A. & Turunen, J. 2012. Carbon loss in drained forestry peatlands in Finland, estimated by re-sampling peatlands surveyed in the 1980s. European Journal of Soil Science 63: 798-807.

Simola, H. 2017. Persistent carbon loss from tilled boreal forest soil humus layer: direct observation across clearcut borders of old-forest stands in Finland. Manuscript, submitted (Jan 2017).

Tuomi, M., Rasinmäki, J., Repo, A.,Vanhala, P. & Liski, J. 2011. Soil carbon model Yasso07 graphical user interface. Environmental Modelling & Software 26, 1358–1362.