Carbon emissions and forest operations: A short guideline for the forestry sector

SOIL CARBON IN GENERAL

Boreal forest soil is an immense storage of carbon (Crowther et al. 2019). The cold climate of the boreal region leads to slow and partial decomposition of dead plant material i.e. litter (Pan et al. 2011). Mineral soil consists of several layers with forest floor being on the top. Forest floor includes the litter layer, with organic residues such as leaves, branches, bark, and stems, and the finely textured organic humus layer. The mineral soil below the forest floor is generally stratified into various layers as well. The most common soil types in Finnish forests are different types of Podzols and Histosols (peat) (Tamminen 2009). In peat soils, the more decomposed layers are located deeper in the peat and less decomposed on the top.

When undisturbed, the soil C storage in forests on mineral soil generally grows at a relatively steady pace, making them sinks of carbon. In forests growing on drained peatlands, the soil is usually a source of carbon to the atmosphere (Lehtonen et al. 2011, Suomen kasvihuonekaasupäästöt 1990-2020). Different natural and anthropogenic changes such as the warming air and soil temperatures or forest management operations can change the soil carbon storage.

FOREST MANAGEMENT AND SOIL CARBON

Clearcutting usually reduces soil carbon stock in the long-term. In forests on mineral soil, this reduction occurs especially in the forest floor and the uppermost mineral soil layer. If the harvesting residues are left on site, the carbon stock in the forest floor is often larger compared to untreated forest directly after clearcutting (e.g. Mayer et al. 2020). The effect has been found to last about 5-10 years (Howard et al. 2004, Falsone et al. 2012, Piirainen et al. 2012, Kishchuk et al. 2016, Strukelj et al. 2015). On the other hand, the residues left on the site start decomposing, which means that they release CO_2 to the atmosphere (Mattson et al. 1987). This release is in any case slower than what the release would be if the residuals were, for instance, burned for bioenergy purposes, but faster if the stand would not have been cut. In general, a clear-cut stand becomes a net source of C to the atmosphere, because the soil carbon storage and possible residues release CO_2 to the atmosphere and there are no trees to photosynthesize and compensate this loss. The effect may last up to 20 years (Pypker & Fredeen 2002, Rannik et al. 2002, Kolari et al. 2004, Fredeen et al. 2007, Mäkiranta et al. 2010).

When residues are collected away from the forest site, also nutrients that would normally enter the forest soil are removed (Clarke et al. 2015, Lim et al. 2020). This could lead to slower tree growth, reduced litter input to the soil and reduced ability of trees to sequester carbon (Clarke et al. 2015). For this reason the Best Practices (for Sustainable Forest Management) in Finland advice to not remove the residues from stands where the nutrient status is low (https://metsanhoidonsuositukset.fi/en). For the same reason, when the residues are removed, they are first left for 2-4 weeks to dry and shed their needles. Following such practice may lead to smaller nutrient losses (Clarke et al. 2015).

The carbon stock in the forest floor is more susceptible to changes than the deeper soil layers. Several studies have reported that the total soil carbon stock (i.e. the stock of forest floor + mineral soil) does not necessarily change with removing residues (Hazlett et al. 2007, Hume et al. 2018, Morris et al. 2019, Lim et al. 2020). However, the carbon stock of the forest floor alone has been shown to decrease after clear-cut with residue removal compared to cased cases where residue was left on site (Clarke et al. 2015, James & Harrison 2016, Clarke et al. 2021). Similarly the soil preparation methods used after clear-cut can also reduce the C storage of forest floor (James & Harrison 2016), while other soil layers are not significantly affected (Jandl et al. 2007, James & Harrison 2016, Mayer et al. 2020). The improved growth of trees may is suggested to balance or outweigh the carbon losses in the ecosystem level (Jandl et al. 2007, Mayer et al. 2020). The effects of soil preparation methods on soil carbon also depend on the intensity of the chosen method. For instance, if also stumps are removed, the carbon stock of the mineral soil may decrease significantly compared to cases where only stems are harvested (Achat et al. 2015).

PEATLAND VS. MINERAL SOIL:

Unfortunately, there is not yet much information available about soil carbon on drained and forested peatlands. The topic has gathered increasing information among scientists, though, and there are projects related to it going on at least in the University of Helsinki, Natural Resources Institute Finland and Finnish Meteorological Institute.

In general, water level plays a much more important role in the decomposition and the carbon dynamics of peatland forests compared to forests on mineral soil. Decomposition requires air, which is not available with high ground water levels. Also the growth of trees requires air so that the roots do not drown. To create more favorable conditions for trees, drainage has been used in peatland forestry. Drainage generally increases decomposition rate and, thus decreases the soil carbon stock (Drzymulska 2016, Maljanen et al. 2010, Ojanen et al. 2013), but the increased growth rates of trees may compensate this loss on the stand carbon stock level (Minkkinen et al. 2001). A clear-cut at a drained peatland forest leads to raised water table level because of diminished transpiration when trees are removed (Sarkkola et al. 2010). This could lead into slower decomposition and release of carbon as methane (CH_4) as the conditions in peat are waterlogged. On the other hand, a recent study in a Finnish drained peatland forest (Korkiakoski et al. 2019) showed that the CO2 emissions greatly increased after a clear-cut (residues were left on the site). The reason for this was reported to be that the loss of photosynthesizing trees and ground vegetation was too much to compensate the decomposition of logging residues and peat.

The increased water level following a clear-cut at drained peatland forests often leads to a need of opening/clearing the ditches in order to decrease the water level so that the seedlings and their roots do not drown. This again increases the decomposition rate and loss of soil C stock. There is, again oxygen available to the decomposing microbes and the seedlings cannot photosynthesize carbon at the same rate than the decomposition process releases it. Continuous cover forestry practices at drained peatland forests could help remaining the water level relatively stable, which could also decrease the loss of carbon from these soils. However, research related to this is currently ongoing and C stocks, sinks and exchange processes in ditched, reforested and clear-cut or unharvested stands are being intensively studied (e.g. Luke, FMI experimental field sites).

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