TORV FORSK

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Climate project
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Emissions of greenhouse gases from peatland managed in forestry and agriculture.

Introductory notes

Peat is an organic soil type that has accumulated above mineral soil or bedrock because of a reduction in decomposition rate of the plant community litter, as a result of water saturation leading to anaerobic conditions. About a quarter of the land area in Sweden, 10 million hectares, is covered by a more or less thick layer of peat. The majority, approximately six million hectares, consists of peatlands, which are characterised by a peat thickness of 30 cm or more (Hånell 2009).

The prerequisite for peat accumulation is that water levels in the ground are sufficiently high that, due to hypoxia, plant residues do not breakdown, but accumulate instead. The accumulation rate in peat soil is around 25 g C per m^2 per year (Frolking et al 2001, Gorham 1995, Tolonen et al 1991). Therefore, during several thousand years C could accumulate in large amounts. According to Franzen (1985), the average depth of all peatlands in Sweden is 1.7 m. The bulk density is 0.094 g dry matter per cm^3, and the C content is 44.5% (from the Swedish National Forest Inventory, n= 788). This means that, on average, peat contains about 160 kg dry matter and 71 kg C per m^2, compared with mineral soil content of approx. 8 kg C per m^2. Calculated for the whole of Sweden, significantly more C is stored in peat-covered land than in mineral soils, and peatlands have a large potential to influence Sweden's national CO_2 emissions.

The peat-covered land has a substantial influence on the flow of carbon dioxide and two other greenhouse gases, methane and nitrous oxide. As indicated above, a wet peatland with a high level of groundwater is a sink for CO_2. But at the same time, such peatlands often emit methane in such amounts that the net effect of CO_2 and CH_4, expressed in CO_2eq, is that wet undrained peatlands become a source of greenhouse gases.

By drained peat-covered land, we mean cases in which, through human action (anthropogenic), drainage is affected such that the water table has been lowered. An untouched peat-covered land would in most cases be described as wet, i.e. a groundwater level about 0-20 cm below the surface. This high water table is a prerequisite for peat growth. Well-drained soils usually have a water table that is around 50 cm or more below the surface. In that case, the upper part of the peat layer is well aerated and the peat decomposes through microbial oxidation. A well-drained peat-covered soil has the potential to enable forestry as well as agriculture. Peat-covered land with a water table at about 50 cm or lower must be considered to be drained since the natural condition of the peat is wetland. The presence of peat thus indicates that the water table must originally have been 0-20 cm below the soil surface instead of 50 cm. Intermediate states, i.e. water tables between 20 and 50 cm can be considered as incompletely drained soil with significantly fewer opportunities for forestry and agricultural production.

Sweden must report national emissions to the Climate Convention, which is a framework of measures to limit climate change. The agreement was adopted in 2011 by the 195 Parties (194 States and the European Union) and came into force in 1994. Concerning peatlands, under this convention Sweden must report emissions from managed land, i.e. forestry and agriculture on peat-covered land as well as land used for peat extraction. This land is usually drained. In contrast, “natural” emissions of greenhouse gases from pristine (undrained) systems are not reported. The acreage of drained peatland and its use is therefore of central importance not only for greenhouse gas emissions but also for how Sweden can meet its international commitments on climate change.

The purpose of this report is to provide an overall assessment of peatland emissions of greenhouse gases.

Methods

This report is mainly based on data on the acreage and emissions presented in various reports. The soil types included in the assessment are: 1) peatland with productive forest (>1 m^3 per ha per year) with or without functioning ditches, 2) peatland without forest (unproductive land, mire) but with ditches, 3) drained peatland with agricultural production, and 4) drained peatland for grass production and grazing. Functioning ditches means ditches that have lowered the water table and allow drainage. Land whose distance to a ditch is about 25 m or less is considered drained.

The greenhouse gases that have been considered are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). They have different climate changing potentials. Because land use as a rule is affected by the flows of all these gases, it is necessary to add them together and express them as a carbon dioxide equivalent gas (CO_2eq), corresponding to the equivalent climate effect of carbon dioxide alone. Thus the assumed conversion factor, GWP_{100}, was 298 for N_2O and 34 for CH_4, based on climate-carbon feedback (IPCC, 2013), i.e. the methane and nitrous oxide values have been multiplied by 34 and 294, respectively, before summing. Sometimes the effect is also expressed as pure C. In doing so, the proportion of C in CO_2 is calculated based on the molecular masses, i.e. 12 of 44. The proportion of C in CO_2 is thus 27 %. Conversely, the amount of CO_2 can be calculated by multiplying the quantity of C by a factor of 3.67.

In parallel, the uptake of CO_2 by forest biomass through tree photosynthesis must also be considered. Drainage is a prerequisite for this uptake to take place. The long-term sequestration of CO_2 can be calculated based on volume growth, using the assumptions that: tree wood density is 0.4 m^3 per tonne, total tree biomass represents 80 % more than tree stem biomass, the C content of the wood is 50 % and the ratio of C to CO_2 is 1:3.67. Thus, the conversion factor between stem volume in m^3 per ha and CO_2 storage as g per m^2 becomes: stem volume*0.4*0.5*1.8*3.66 * 100 = 132. Assuming an average growth rate of 4-8 m^3 per ha per year thus gives an absorption rate of 528-1056 g CO_2 per m^2 per year.

Results and discussion

Emissions from forestry and drained mires

Acreage

The international (FAO) definition of forest is land with a contiguous area of trees covering more than 0.5 ha, with a tree height of more than five meters and a crown cover of more than ten percent, or which has the potential to reach this height and crown cover without measures to increase production. The Swedish national concept of productive forest limits the forest to land that has an average production of at least 1 m^3 per ha per year.

The following figures refer mainly to peatlands >30 cm. This is because there is limited published information available on peatlands <30 cm, both in terms of acreage and emissions. It must therefore be emphasised that the assessments of emissions are underestimated.

Lindgren and Lundblad (2014) state in a report to the SNV a total of 877 000 ha of drained forest based on the Swedish National Inventory of Forests. In this case forest uses the international definition. Hånell (2009) estimated from the National Inventory of Forests 2003-2007 that the acreage of drained peatland (peat >30 cm) totals 1.097 Mha of which 0.746 Mha were considered productive forest (>1 m^3/ha per year) and 0.35 Mha are mires without productive forest. These two estimates agree well. They are also in agreement with an earlier study by von Arnold et al (2005). Lindgren and Lundblad (2014) reported a slightly higher value than Hånell (2009), which is probably due to the latter having used the more narrow Swedish definition of forest. We therefore have a solid basis for the assumption that there are about 0.88 Mha of drained forest according to the international definition (on peat >30 cm) whose emissions must be reported under the Climate Convention.

Drained land in these studies means the presence of a ditch within 25 m. The question then becomes whether there are also forests on peat without a ditch within 25 m. According to Hånell (2009) the acreage of undrained peatland forestry is 0.99 Mha, according to the Swedish definition of productive forest. However, this is an underestimation compared to use of the international definition. Recalculated according to the international definition this corresponds to 1.21 Mha. The recalculation is based on the relation between forest land area according to the national Swedish definition (23 Mha) and international definition (28 Mha), i.e. a factor of 1.22.

Beyond this there is, as mentioned above, drained land without forest. This area is here assessed as the difference between the total area drained peatland (1.097 Mha, Hånell 2009) and the area of drained peatland with forest according to international definition (0,877 Mha, Lindgren & Lundblad 2014), i.e. 0,22 Mha (mire). This peatland will not be included in reporting under the Climate Convention.

Lastly, there is peatland without forest with some effect from ditches, where the ditches are beyond 25 m, but close enough that a certain amount of drainage is discernable. This area is thus also under anthropogenic influence. However, there is currently no basis for quantifying these areas, which were therefore not included in the acreage estimates. The reported acreage data in Figure 1 can be regarded as an underestimate.

Productive forest land on peat with ditches: 0.88 Mha
Productive forest land on peat without ditches: 1.21 Mha
Peatland with ditches but without forestry (mires): 0,22 Mha

Figure 1. Acreages of peatland under anthropogenic influence from forestry and/or drainage, Mha. Total area 2.31 Mha. Forest land defined according to international definition.

As Fig. 1 shows, not all forest is drained with currently functioning ditches according to the definition. However, one can assume that the water table is fairly low. Possible explanations may be that previous ditches enabled forest establishment and that tree transpiration now keeps water away, or that functioning ditches are located just outside the 25 m limit. We therefore have a solid basis to assume that productive forestry peatland emits roughly the same amount of greenhouse gases as drained land - and thus is anthropogenically affected land.

In total there is at least 1.21+0.88+0.22 = 2.31 Mha of anthropogenically affected forest and mire, of which 1.21+0.88 = 2.09 Mha is productive forest. If one extends this concept to all peat-covered land, i.e. even peat thinner than 30 cm, then the area of productive forest on peat totals 5 Mha (Hånell 2009).

Emissions from productive forest peatland and ditch-affected mires

Drained peat-covered land emits large quantities of greenhouse gases, CO_2 as well as CH_4 and N_2O, and is therefore a significant source of greenhouse gases. Each one of these gases is affected by the peat composition and water table position in its own way.

Emissions of greenhouse gases from peatland have been studied and reported in a very great number of scientific reports. The results are sometimes difficult to interpret and compare, because e.g. measuring methodology, time of the year and site conditions vary between the studies. This report shows the results from a literature review by Jordan and Olsson (2015) that is based on about 30 scientific publications from boreal peatlands in Sweden, Finland and Canada.

For peatland with a water table at 30 cm or deeper, and depending on peat composition (e.g. N content) emissions from peat vary between 5.23 and 9.11 tonnes of CO_2eq per ha and year (CO_2, CH_4 and N_2O in total), depending on the variation in hydrology and peat properties. To give an idea of the size of these emissions, it can be compared with emissions of CO_2 from the combustion of 8-12 m^3 of wood (solid wood), or with driving a mid-sized car 28 000-46 000 km. It is also of the same magnitude as the amount of greenhouse gases that is annually emitted in most EU countries per capita. To some extent however, emissions from drained peatlands are, at least partially, offset by forestry and the associated photosynthetic uptake of CO_2.

The emissions of CO_2 alone for peatland with a water table at 30 cm or deeper vary according to the review by Jordan and Olsson (2015) between 385 and 779 g per m^2 and year. This corresponds to 105 - 212 g C per m2 and year, equal to 8.9 -18.0 Mt CO_2 for 2.31 Mha drain affected forested peatlands and mires occurring in Sweden (Fig. 1). This corresponds to an anual loss of peat amounting to 58 - 118 Mm3 or 5.5 - 11.1 Mt dry weight. Based on an energy content in peat of 3.5 MWh per ton dry weight the annual peat loss corresponds to the energy content in 1.9 - 3.9 Mm3 fuel oil.

Based on the estimate of 2.31 Mha (see Fig. 1) the emissions of CO_2, CH_4 and N_2O amount to a total of 12.1-21.0 Mt CO_2eq per year (Fig. 2). It should be emphasised that the peat-covered land with peat <30 cm is not included, and therefore the emissions from all the peat-covered land with forest and drained mire is considerably higher. Drained land where the ditches are located >25 m away are also not included. This stated value of 12.1 to 21.0 Mt of CO_2eq must therefore be regarded as a minimum level.

These emissions can be compared to Sweden's reporting in 2013 of a total of 55.8 Mt CO_2 including 18.1 Mt CO_2 from all domestic traffic (Table 1). The conclusion is that emissions from peat land with forest production including drained mire amount to a value that is at least 20-35 % of Sweden's total emissions, or a value of the same magnitude as all Swedish domestic traffic.

Table 1. Sweden's reported greenhouse gas emissions 2013 in Mt CO_2eq per year, according to the Swedish Environmental Protection Agency's website 2014 (http://www.naturvardsverket.se/Sa-mar-miljon/Statistik-A-O/Vaxthusgaser--nationella-utslapp/.)

Sector	
Road transport, passenger car	11.1
Road transport, trucks and buses	6.7
Other domestic transport	1.29
Industry and product use	6.54
Combustion in industry	8.08
Combustion in services, households, agriculture, forestry and fisheries	3.08
Energy industry	10.08
Agriculture	6.9
Waste disposal	1.62

Military, diffuse emissions and users of solvents	0.97
SUM	**55.77**

Absorption into tree biomass

How the uptake of CO_2 into biomass should be assessed can be a controversial question. Note that of the total sequestration a maximum of 56 % is stored in commercially viable raw wood. Most of the remainder, i.e. annual litter and logging residues, will go back to the atmosphere within a decade or two as carbon dioxide from decomposition. In addition to that, not all stem wood will be harvested, but a portion of the stem wood will be left in the forest to decompose. Finally, the use of stem wood is also an important but controversial issue. The greatest benefit from a climatic perspective is from society's use as a substitution for other materials that are associated with large emissions of CO_2.

Depending on what proportions of a cubic metre of raw wood material is used in various types of consumption, the effect of substitution in the Swedish production system is estimated at 600-800 kg of carbon dioxide per harvested cubic meter (Larsson et al, 2009). Net annual harvesting in Sweden was 68.9 Mm^3 in 2012 (Swedish Statistical Yearbook of Forestry 2013), i.e. in average 2.98 m^3 per ha and year (23.1 Mha). Assuming that the distribution of areas is weighted equally between productive forest peatlands (2.09 Mha, Fig. 1) and other productive forest, the net felling of the productive forest peatland alone is 6.23 Mm^3 per year. The effect of substitution can, under these conditions, be estimated to be 3.7-5.0 Mt CO_2 (Fig. 2). This represents approximately 19-46 % of the emissions from peat in the same area (2.09 Mha).

The value of this substitution effect is only visible indirectly in the report to the Climate Convention, namely through the required emissions figures, such as fossil fuel combustion, being reduced.

The direct effect of the forest should be reported in the form of changes to the C pool in the standing forest, i.e. growth minus emissions by felling or by other causes. To calculate this change in stock, we can assume that the productive forest peatlands have the same growth conditions as for Sweden as a whole. The area of productive forest peatlands represents 8.2 % of the entire productive forest area in Sweden. The total growing stock in 2013 was 3002 Mm^3 (equivalent to 130 m^3 per ha on average). Since 1926, the total stock increased by an average of about 16 Mm^3 per year. Between the years 2011 and 2013 the increase in growing stock in Sweden averaged 29.2 Mm^3 per year. Because the productive forest peatland share was 8.2 %, we can thus estimate that the growing stock on peatland alone increased by approximately 2.4 Mm^3 during the past two years, corresponding to 1.3 m^3 per ha per year. Following the above figures, this equals a sequestration of 166 g CO_2 per m^2 per year. This represents ca. 20-33 % of the 500-800 g CO_2 per m^2 per year emissions from the ground, and is equivalent to 3,47 Mt of CO_2 from 2.09 Mha (Fig. 2).

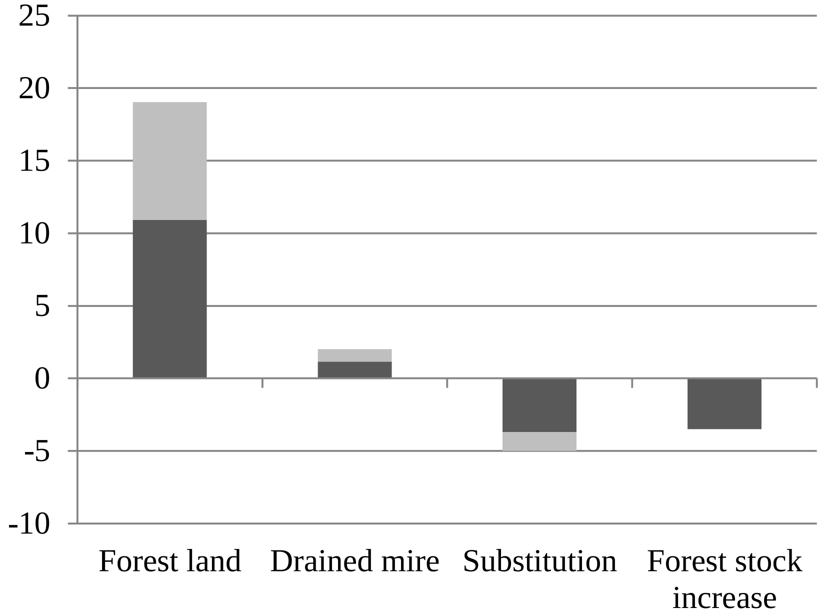

Figure 2. Summary figure of fluxes from forest on peat soil and from drained mire, Mt CO_2eq per year (the types shown in Figure 2). Positive values indicate flow into the atmosphere. Negative values indicate flow from the atmosphere. The gray portion of each bar indicates the uncertainty range.

Emissions from drained peatland used for agricultural purposes

The area of drained peatlands used for agrarian production is, according to Berglund et al. (2009), estimated at 268 000 ha. Lindgren and Lundblad (2014) conclude on the basis of a literature review that emissions of CO_2 from drained organic soils can be reasonably estimated to around 610 g CO_2 per m^2 per year. They also conclude that N_2O emissions are estimated at 1.3 g N_2O per m^2 per year. With an estimated global warming potential of

298, this corresponds to 387 g CO_2eq per ha. Lindgren and Lundblad (2014) estimate the emissions of CH_4 to be 1.3 g per m^2 per year. This is equivalent to 44 g CO_2eq at a global warming potential of 34. Total emissions are thus 1041 g CO_2eq per ha per year. The value for all drained arable land is thus 2.8 Mt of CO_2eq emissions.

Emissions from grassland on peat

Similarly to the productive forest and agricultural land, grassland greenhouse gas emissions must also be reported under the Climate Convention (grassland). In Sweden the grassland concept refers to pasture (semi-natural pastures) used for grazing with e.g. cattle and sheep. The area of grassland on peat soil is estimated to be 23 000 ha (Lindgren and Lundblad 2014). The total area of pasture amounts (according to the Swedish Yearbook of Agricultural Statistics 2012) to 452 000 ha. The grazed area of peatland is thus only ca. 5 % of the total grazed area. According to Lindgren and Lundblad (2014) emissions of CO_2, N_2O and CH_4 are roughly on a par with that of forest, i.e. between 523 and 911 g CO_2eq per m^2 and year (see the above section on forest). For all peatland with grazing this means approximately 0.1-0.2 Mt CO_2eq per year.

Final conclusions

The total affected peatland area (> 30cm peat), which is either productive forest land, drained mire, arable land or pasture is estimated to be 2.60 Mha. Total emissions of the greenhouse gases carbon dioxide, nitrous oxide and methane from this land amount to 15-24 Mt CO_2eq per year. Due to its large area, forestry land use generates the greatest emissions, 11-19 Mt CO_2eq per year (Fig.3). These emissions can be compared with Sweden's report in 2013 of total emissions being 55.8 Mt CO_2 including 18.5 Mt CO_2 from all domestic trafficrt (Table 1). The conclusion is that emissions from peat land with productive forest, drained mire, arable and grassland is at least 25-40 % of Sweden's total emissions, in other words up to twice as much as all domestic passenger car transport emissions. It should also be pointed out that land with peat <30 cm is not included and that this area is larger than that with peat >30 cm. Peat-covered land with ditches, where the ditches are more than 25 m away, are not considered. The estimated emissions should therefore be considered to be somewhat underestimated..

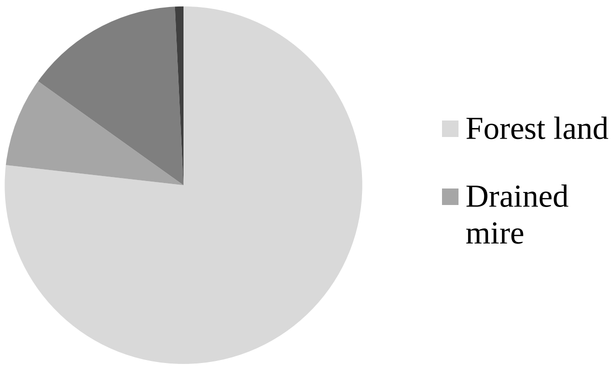

Figure 3 Approximate distributions of emissions between forest on peat, drained mire, arable and grassland. Total emissions from these types of land represent 15-24 Mt of CO_2eq per year (2.6 Mha).

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