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

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Climate project
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Summary

Peat is an organic soil that is accumulated because water saturation and lack of oxygen has substantially reduced the decomposition of plant residues. Sweden has around 10M ha of peat covered land whereof 6M ha is categorized as peat land because the peat layer is thicker than 30cm. About 2.6M ha of the peat land is hydrologically more or less affected by ditching in order to enable forestry or agriculture. This report aims at describing greenhouse-gas balances at this hydrologically affected land in a boreal environment, and is based on a large number of scientific reports. The greenhouse gases considered are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Their total is determined with respect to their climate impact, respectively, and expressed as CO_2 eq.

The results show that the area of hydrologically affected peatland amounts to 2.09M ha with productive forestry with or without ditches within 25m, plus 0.22M ha mire without productive forestry but with ditches within 25 m. In addition, 0.27M ha of arable land and 0.02M ha of grassland is occurring on peatland with ditches. The amount of greenhouse gases that is emitted is dependent on e.g. the groundwater level, vegetation type and nutrient availability. In average, in Sweden, the emissions from peatland with forestry and mire with the groundwater level deeper than 30 cm is assessed to 5-9 ton CO_2 eq per ha and year. For arable land and grassland the average emission is 10.4 ton CO_2 eq per and year. In total, the emissions from the 2.6M ha of drainage affected land amount to between 15 and 24 M ton CO_2 eq per year. This is about equal to the emissions from all domestic passenger car transport in Sweden.

The main part of the total emissions, 10.9-19.0M ton originates from peatland with productive forestry. However, the results also show that there is a substantial uptake of CO_2 in tree biomass. The sum of the net CO_2 uptake as a result of the annual increase in forest stock, and the substitution potential from harvested wood is estimated to 7.2-8.5 Mton CO_2 per year. This means that the emissions from the peat on land with productive forestry is compensated by the emission reduction impact of forestry to about 50%.

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). This peat-covered land has a substantial influence on the flow of carbon dioxide and two other greenhouse gases, methane and nitrous oxide. 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. This means that on average peat contains about 59 kg C per m^2, compared with mineral soil content of approx. 8 kg C per m^2. Calculated for the whole of Sweden, this means that 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.

As indicated above, a wet peatland with a high level of groundwater is also 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 both forestry and 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 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, GWP100, 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 tonne per m^3 , 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 uptake 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 clearly an underestimation compared to use of the international definition. Recalculated to international definition this corresponds to 1.21 Mha. The recalculation is based on the area relation between forest land according to Swedish definition (23M ha) and international definition (28M ha), i.e. a factor of 1.22 between them.

Beyond this there is, as mentioned above, ditched land without forest. This area amounts to the difference between total area ditched peatland (1.097 ha, Hånell 2009) and the area ditched peatland with forest according to international definition (0.877 M ha, Lindgren & Lundblad 2014), i.e. 0.22M ha (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 with ditches	0.88 Mha
Productive forest land without ditches	1.21 Mh
Ditched land without productive forest (mire)	0.22 Ma

Figure 1. Area peatland which is hydrologically affected by forest production and/or ditching. Total area 2.31 Mha (farmland not included). Productive forestry is defined according to international definition (FAO).

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 0.88 + 1.21 + 0.22 = 3.31M ha of anthropogenically affected forest and mire, of which 0.88 + 1.21 = 2.09M ha 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 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 of these gases is affected by peat composition and water table position in their own ways.

For peat soils 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_2 e per ha per year (according to a literature review by de Jong et al, 2015), 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. To some extent however, emissions from drained peatlands are, at least partially, offset by forestry and the associated photosynthetic uptake of CO_2.

Based on the estimate of 2.31 Mha (see Fig. 1) emissions 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_2 must therefore be regarded as a minimum level.

These emissions can be compared to Sweden's reporting in 2014 of a total of 54.4 Mt CO_2 including 17.8 Mt CO_2 from domestic passenger car transport (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 about equal to the emissions from all domestic passenger car transport.

Table 1. Sweden's reported greenhouse gas emissions in Mt CO_2eq per year 2014, according to the Swedish Environmental Protection Agency's website 2016 (http://www.naturvardsverket.se/Sa-mar-miljon/Statistik-A-O/Vaxthusgaser--nationella-utslapp/.)

Sector	
Road transport, trucks and buses	3.69
Other domestic transport	17.77
Energy production	6.77
Agriculture	7.14
Industrial Processes	14.71
Combustion in services, households, agriculture and forestry	1.34
Waste disposal	1.52
SUMMA	**54.38**

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 mCO_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).

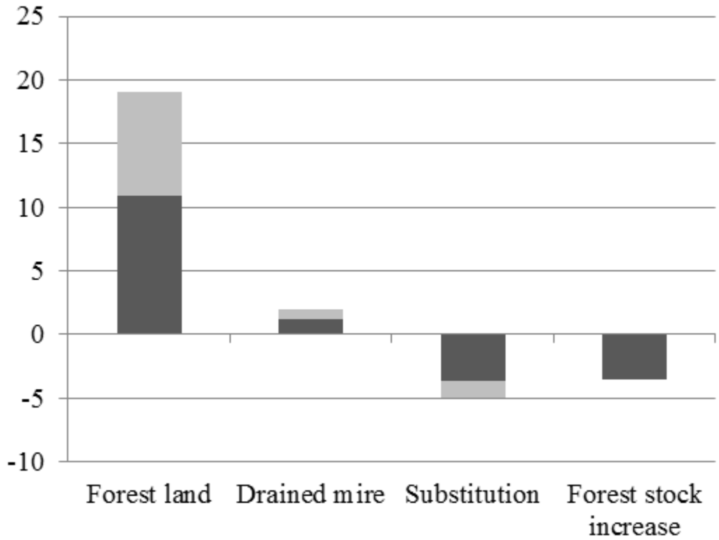

Figure 2. Summary figure of fluxes from forest on peat soil and from drained mire, Mt CO_2eq per year (the types shown in Figure 2). Positive values indicate flow into the atmosphere. Negative values indicate flow from the atmosphere. The gray portion of each bar indicates the uncertainty range.

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 Lundmark (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 Lundmark (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 Lundmark 2014). The total area of pasture in 2019 (according to the Swedish Yearbook of Agricultural Statistics 2012) will be 452 000 ha. The grazed area of peatland is thus only ca. 5 % of the total grazed area. According to Lindgren and Lundmark (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 per 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 2.51 Mha. Total emissions of the greenhouse gases carbon dioxide, nitrous oxide and methane from this land amount to 14.5-23.2 Mt CO_2eq per year. Due to its large area, forestry land use generates the greatest emissions, 9.8-17.0 Mt CO_2e per year. These emissions can be compared with Sweden's report in 2012 of total emissions being 54.4 Mt CO_2 including 17.8 Mt CO_2 from domestic passenger car transport (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. These estimated emissions should therefore be considered to be somewhat underestimated.

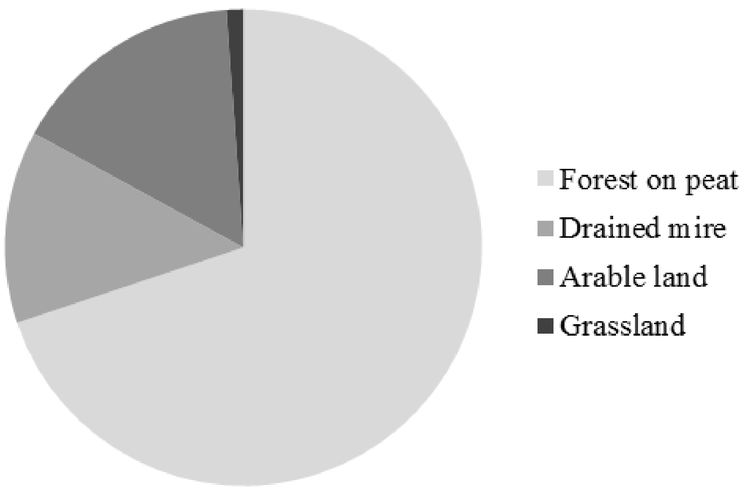

Figure 3 Approximate distributions of emissions between forest on peat, drained mire, arable and grassland. Total emissions from these types of land represent 14.5-23.2 Mt of CO_2*eq per year (2.5 Mha).*

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Summary for decision makers

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Greenhouse gases from drained peatland

Source: TorvForsk report no 15, Olsson, professor em, SLU

Peat amount

The area of peat covered land in Sweden amounts to about 10 million ha. Of this area, ca. 6 million ha ha, has a peat layer thicker than 30 cm and is classified as peatland. About 2.6 million ha of the peatland, i.e, almost half the area, is affected by drainage carried out for enabling agriculture and forestry.

Most of what is drained, 2.1 million ha, is productive forest land (according to international definition of forest land), whereas 0,3 million ha ha is agricultural land and 0,2 million ha ha is land where drainage has failed and is classified as mire without any forest production.

Carbondioxide equivalents

The drained peatlands emit large amounts of greenhouse gases, carbon dioxide as well as methane and dinitrous oxide, and are for this reason a significant source for greenhouse gases. The cumulative effect of these gases can be determined by assessing the amount of carbon dioxide, CO_2, that corresponds to the climate effect of methane and nitrous oxide. The sum is expressed as carbon dioxide equivalents (CO_2eq).

One turn around the Earth

For peatlands with a groundwater table at 30 cm or deeper the emissions of the three greenhouse gases from peat vary between 5.2 and 9.1 ton CO_2eq per ha and year, depending on differences in hydrology and peat properties. To visualize the size of this emission one might compare it with the emitted amount of carbon dioxide when driving a medium-sized car 28000 - 46000 km, i.e. one turn around the Earth.

Amount of greenhouse gases

The total emission of the greenhouse gases carbon dioxide, methane and nitrous oxide from drained peatland in Sweden amounts to 12–21 million ton CO_2eq per year. This is at the same level as the emissions from all domestic traffic in Sweden and one third of Sweden's reported total emissions of greenhouse gases 2013 (in total 54.4 million ton CO_2eq). Of the drained peatlands in Sweden, the part with productive forestry is the one with the biggest emissions. This is due to the large area. The emissions amount to 10-17 million ton CO_2eq per year.

The size depends on drainage

The largest proportion of the emitted greenhouse gases from drained peatlands is made up of carbon dioxide, 68-100 %. This is due to the increased oxygen availability, following drainage, enabling oxidation of the peat.

At undrained peatlands the emissions of greenhouse gases might be even bigger, but, due to lack of oxygen, the emissions occur not as carbon dioxide but as methane. On the contrary, at wet undrained peatlands, a carbon dioxide sink might occur due to peat growth. Consequently, drainage can result in peatlands changing from being net sinks to being net sources of carbon dioxide.

Disappear to no use

The amount of lost through oxidation following drainage (2,6 miljoner ha) is 8-14 million ton or 81-148 million m^3. The amount of energy that in this way annually is lost is equal to the energy content in 2,7 – 4,9 million m^3 fuel oil.

The role of forestry

There is significant uptake of carbon dioxide at 2.1 million ha drained peatland due to the growth of forest biomass. The trees fix through photosynthesis carbon dioxide, but all the uptake do not be considered as a long-term sink because a big part of the uptake is recycled to the atmosphere due to decomposition of dead plant residues (litter) and the fact that wood is used in the processing industries like pulp industry.

Could be a sink

However, there is a long-term increase of the standing forest biomass. Furthermore, wood can substitute fossil fuels and e.g. concrete for construction. This results in a sink and avoided emissions which together correspond to about 50 % of the emissions from peatland with productive forestry.

Management

Peat cutting in combination with an effective use of the peat and regenerated forest might turn the drained peatland system into a substantial sink for carbon dioxide. In addition, creation of new wetlands and lakes after finished peat cutting might be suitable measures.

Swedish Peat Research Foundation

The Swedish Peat Research Foundation aims at increasing the knowledge of peat and peatland, and to initiate, perform and evaluate research approaches that are of importance for the management and preservation of peatlands.

The Swedish Peat Research Foundation is a research foundation that was formed 1983 by representatives from the peat branch. It aims at initiating, planning, performing and evaluating research and to undertake development initiatives which are of importance for the peat branch. The contribution by the foundation is:

- to pick up research suggestions and ideas concerning further development for peat management, and which demands cooperation between different disciplines.
- to stimulate and support long term and sustainable cooperation and competence strengthening regarding peat management that is of general significance for the entire peat branch, or parts of it.
- to, through reports and seminars etc., contribute to dissemination of new knowledge and to technic transfer. The actions should aim at enabling results to be used in practice.

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