Slutrapport

Projekttitel

Vitmossa (Sphagnum) är framtidens klimatvänliga torvsubstitut i våra trädgårdar

Projektnummer: O-17-22-980

Projekttidsperiod: 2018-01-01 – 2021-06-30

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Del 1: Utförlig sammanfattning

Kort beskrivning av syftet, metoder, huvudsakliga resultat och nytta för näringen samt rekommendationer. Sammanfattningen måste skrivas på engelska om rapporten är på svenska, och vice-versa.

Syftet med projektet var att introducera *Sphagnum* Farming (odling av vitmossa) på avslutade torvtäkt i Sverige som ett klimatsmart efterbehandlingsalternativ (torvbildande kolsänka) och för att samtidigt klimatvänlig kunna producera högkvalitativ biomassa till odlingssubstrat.
Metoder: I samarbete med Hasselfors Garden/Neova valdes en del av Ekebymossen (Örebro län), där torvtäktsverksamheten är avslutad, till att vara vårt fältforskningsområde för etableringen och odlingen av vitmossor på 3 ha under åren 2018 till våren 2021. Växthusgasmätningar med manuella och automatiska kontinuerliga system och analyser i vatten och torv har gjorts och flygbilder med drönare samt transektmätningar för vegetationskartering har tagits under alla år. Etablerade vitmossor på andra återställda torvmarker, såsom Porla, Läsarmossen och Toftmossen, besöktes under projektets löptid för att mäta vitmossornas tillväxt. Arterna S. papillosum, S. squarossum, S. riparium, S. fallax har testats i växthuset med avseende

Projekt har fått finansiering genom:
Stiftelsen Lantbruksforskning

på odlingssubstrat mot den konventionella låghumifierade torven ('white peat') som används inom den professionella och hobbymässiga trädgårdsodlingen.
Huvudsakliga resultat: Vitmossorna kan etablera sig inom 1-3 år efter återvätningen så länge en god vattenförsörjning är garanterad. Det leder till en exponentiell tillväxt på ytan och på höjden. Strax efter återvätningen kommer annan våtmarksvegetation, som starr, tuvull och vass, att etablera sig. Dessa pionjärväxter ger de små vitmossorna bra skydd mot sol och vind. I början är vitmossebeståndet inget rent bestånd. Det kommer att ändra sig när vitmossorna har tagit över ekosystemet genom att sänka pH-värdet.
I etablerade bestånd (äldre än 10 år) med en genomsnittlig tillväxt på cirka 7 ton torrsubstans per hektar och år (tillväxthastigheter på 20 cm för *Sphagnum* fuscum, S. fallax, S. riparium och S. squarrosum observerades) kan en årlig totalproduktion på 3,5 miljoner ton uppnås (omkring 500 000 hektar redan påverkade torvmarker bedöms kunna omvandlas till paludikultur i Sverige) samtidigt som vi minskar växthusgasutsläppen med ca 3-5 miljoner ton per år. Äldre vitmossebestånd tar upp mer CO_2 och är därmed en effektivare kolsänka. Detta pga en högre täckningsgrad av vegetationen, dvs. att andelen av bar torv på ytan är nästan noll.
Växtodlingsexperimentet visade att vitmossorna kan bli ett konkurrenskraftigt substrat för växtodling. Alla testade växter (Basilika och Tagetes) etablerade sig i alla krukor med vitmossor.
Vattenkvaliteten förändrades från höga till låga koncentrationer för många ämnen dock varierar koncentrationen av kväve fortfarande. Vattenfärgen har ändrats synligt från ganska brunaktigt direkt efter återvätningen till ett mer klart vatten.
Nytta för näringen och rekommendationer: Vitmossa som förnybart odlingssubstrat bidrar till hållbar utveckling av de torvmarker som emitterar stora mängder av växthusgaser. Den har också den största potentialen att lösa ett framtida substratbehov i fall det blir ett (politiskt) förbud mot torvanvändning eftersom vitmossor har samma kemiska och fysikaliska egenskaper som torv (samma utgångsmaterial, bara några 100 – 1000 år yngre) och kan därmed bli ett konkurrenskraftigt substrat för växtodling. Eftersom vitmossa kan förmås att växa på bl.a. befintlig eller tidigare torvtäktsareal kan jordtillverkare säkerställa arbetstillfällen i glesbebyggda områden, dvs. att personalen på torvtäkten får behålla sina jobb (skörd av vitmossa i stället för torvbruk). Det samma gäller för arbetstillfällen inom trädgårdsnäringen – det blir bara ett substratbyte. Detta bidrar till att även denna näring får en ökad hållbarhet, och att produkten blir mer accepterad av kunderna. Jordtillverkarna är i behov av stora mängder enhetligt material och odlad *Sphagnum* har många goda egenskaper som liknar torvens, något som är svårt att uppnå med andra alternativ. Detta material finns redan på marknaden idag (dock inte den svenska) och jordtillverkarna ser en kraftigt ökad efterfrågan.
Att införa storskalig odling av förnybara råvaror och att uppskatta potentiella utsläpp eller upptag av växthusgaser efter återvätning av torvtäkter är viktiga kunskaper som ger Sverige möjlighet att rapportera rätt utsläpp från dessa platser i den nationella klimatrapporteringen och på internationell nivå. Denna kvalitet uppnås bara med mångåriga projekt. *Sphagnum* Farming borde vägas in i efterbehandlingsplanen vid sidan av andra alternativ som till exempel skogsodling.

Del 2: Rapporten (max 10 sidor)

Inledning

Bakgrund och syfte.

Peat extraction for energy production and for growing media (substrates for horticulture), has a long tradition in Northern Europe (1), also in Sweden. To restore the ecosystem functions and thereby the providing services for humans, the Swedish law requires remediation after the peat has been extracted (2). Finding the perfect after-use for peatlands can be difficult, since many different factors influence the success of restoration, like relief, degradation, thickness and characteristics of remaining peat or rewetting possibilities. These factors need to be considered before deciding on fitting measures (3).
Further, peat use in horticulture is increasingly discussed due to its climate-relevance and the disturbance of mires (not in Sweden since only already drained peatlands are used) and peatlands. At the same time, peat is the most important, natural horticultural growing media constituent and only a few other organic constituents have gained acceptance in horticulture, but cannot adequately replace peat in quality and quantity. Consequently, sustainable development concepts such as wet agriculture (paludiculture) are needed (4) and a new resource for growing media constituents should be found. Peat mosses (*Sphagnum* spp.; figure 1) are in the focus, as they are the main peat forming plants in bogs and as they have similar physical, chemical and biological characteristics as the most common growing media constituent peat (5).

Figure 1: *Sphagnum* squarrosum (Spärrvitmossa)

The cultivation of peat mosses (*Sphagnum* farming) on badly drained, and thus unproductive, but also on rewetted extracted peatlands seems to be one of the most promising alternatives to obtain a sustainable peat substitute and a climate-smart land use. Paludicultures on rewetted peatlands contribute to climate change mitigation by reducing greenhouse gas (GHG) emissions from drained peatlands and by replacing fossil resources by renewable biomass alternatives. Thus, peat companies (as well as gardening and landscape companies) can actively contribute to a climate-smart cultivation (figure 2) with a high economically benefit on former GHG emitter sites. An industrial big-scale land-use on rewetted extracted peatlands would then reduce Sweden’s climatic impact in general and would achieve the environmental objectives

"Responsible consumption and production", "Sustainable Use of Ecosystems on Land" and "Thriving Wetlands" in particular.

Figure 2: Harvesting of peat mosses without disturbing the farming fields (picture taken in Germany)

Materiell och metoder

Du kan använda underrubriker för olika delar av projektet (till exempel laboratorieexperiment, fältförsök)

In cooperation with Hasselfors Garden/Neova, a part of Ekebymossen (Örebro County), where the peat extraction has ended, was selected to be our field research area for the establishment and cultivation of peat mosses (Sphagnum) on 3 ha (figure 3) during the years 2018 to spring 2021. Hasselfors Garden/Neova provided the project with a small barrack, boardwalks and a platform in the shallow water to facilitate the scientific work.

Figure 3: Terminated peat extraction site at Ekebymossen before *Sphagnum* spreading and rewetting in autumn 2018

In 2018, fragments of different *Sphagnum* species were spread in different mixing ratios (pure Sphagnum and mixed with peat) on about two ha. In 2019, an additional hectare was inoculated with local *Sphagnum* and then rewetted. Due to the pandemic, the delivery of 10 m^3 of *Sphagnum* for cultivation has been postponed until spring 2021. Greenhouse gas measurements with manual and automatic continuous systems and water and peat analyses have been made and aerial photographs with a drone (DJI Phantom 4 at a height of 24 m) as well as transect measurements for vegetation mapping have been taken during all years. Established *Sphagnum* sites on other restored

peatlands, such as Porla, Läsarmossen and Toftmossen, were visited during the term of the project to measure the *Sphagnum* growth.
The species S. papillosum, S. squarossum, S. riparium, S. fallax have been tested in the greenhouse with regard to cultivation substrates against the conventional 'white peat' used in professional and hobby horticulture.
Milestones during the project can be seen in figure 4.

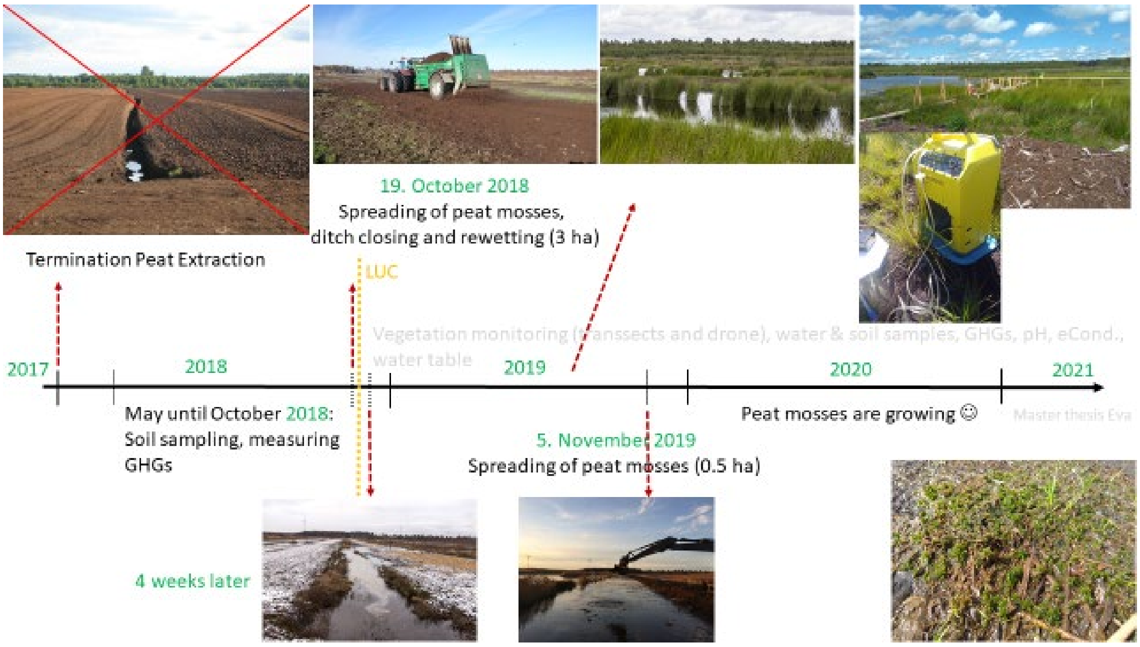


Figure 4: Time schedule, steps and observations in the project

Resultat och diskussion

Du kan använda underrubriker för olika delar av projektet (till exempel laboratorieexperiment, fältförsök). Variation kring medelvärden (till exempel SE, SEM) och resultat från statistiska analyser ska anges i figur eller tabell om tillämpligt.

Rewetting, Sphagnum growth and greenhouse gas emissions

Rewetting introduced typical wetland/peatland vegetation already after the first winter at Ekebymossen. Over the project period, non-inundated bare peat patches have been vegetated (figure 5 +6) and habitats for migratory and breeding birds have been created.

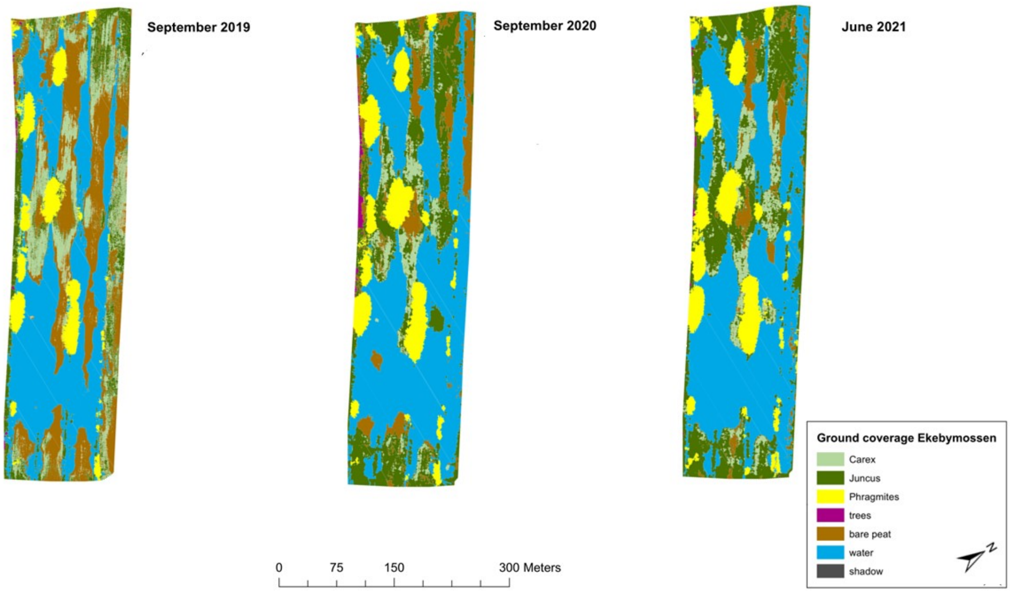


Figure 5: Vegetation development at Ekebymossen after rewetting in autumn 2018 (GIS by cand. M.Sc.-Stud. Eva Weber)

Sphagnum has established as "understorey" in Carex and Juncus (figure 7). Therefore, it is not visible (yet) in figure 5 and 6.

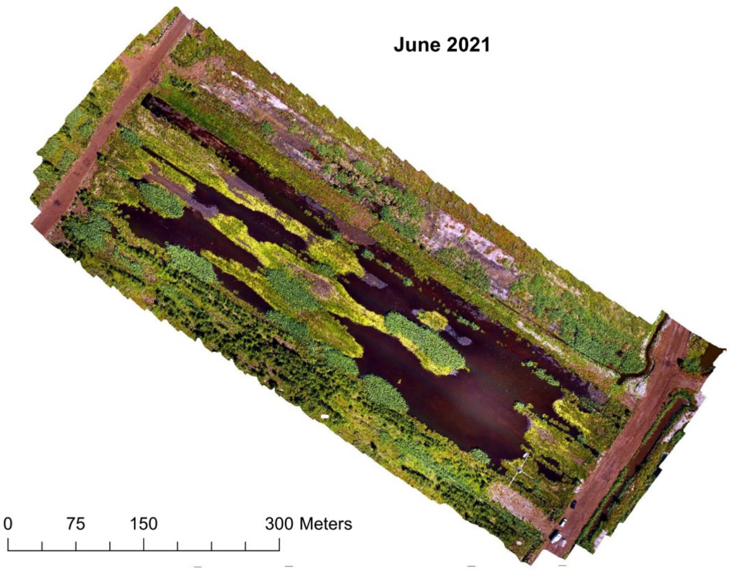


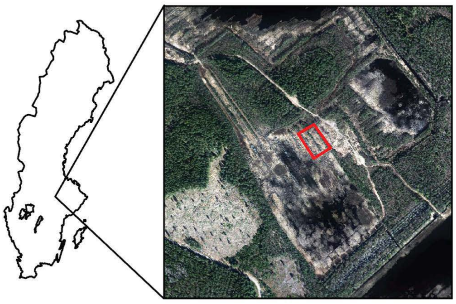
Figure 6: Aerial photograph of the rewetted Ekebymossen (taken with DJI Phantom 4 at a height of 24 m)

Figure 7: *Sphagnum* protected by pioneer plants such as Carex spp.

Rewetting stops CO_2 emissions immediately because it leads to saturated conditions in the remaining peat. Thus, peat decomposition and CO_2 emissions are prevented from the first day of rewetting. However, rewetting of former agricultural used peatlands can cause an initial increase in CH_4 emission fluxes due to the presence of easily decomposable biomass before inundation. Many authors see this as a transient phenomenon – the effect of which will reduce with time (6, 7, 8). In 2019 and 2020, one resp. two years after rewetting, no CH_4 emission has been detected due to the lack of fresh vegetation at Ekebymossen. In other Swedish rewetted extracted peatlands, low CH_4 emissions from the water body have been detected (2). In 2021 during the summer, high CO_2 uptake was measured creating a carbon sink despite of low CH_4 emissions. This is in line with other research about peatland rewetting. As long as an ecosystem takes up more CO_2 as it emits CH_4, "warnings against CH_4 emissions from rewetted peatlands are therefore unjustified and counterproductive" (9).

How fast *Sphagnum* can establish after rewetting could be monitored in Toftmossen, another field site near Surahammar (figure 8). No *Sphagnum* spp. was observed in 2010. The first patches occurred in 2012 and were growing exponentially over the years with a small decline in 2019 (not shown here) and 2020 due to the very dry summer in 2018. Simultaneously, bare peat areas decreased and were covered mostly by fen vegetation but also by *Sphagnum*. Depending on temperature, soil moisture or height of water table and light, ecotopes with peatland vegetation can be sinks or sources for carbon whereas bare peat sites are carbon sources only.
Sphagnum growth at the Porla rewetted peatland (rewetting in 1998) was up to 30 cm per year (figure 9), which would account for an annual total production of 3.5 million tons growing media (about 500,000 hectares of already drained peatlands are estimated to be able to be converted to paludiculture in Sweden). Simultaneously, greenhouse gas emissions would be reduce by about 3-5 million tons per year.

Figure 9: Fresh *Sphagnum* from one vegetation season



	Area (m^2)					
År	Vatten	Kärr-vegetation	Träd	Bar Torv	Sphagnum spp.	Total
2010	435	1033	1567	713	0	3748
2012	214	1699	1530	292	12	3747
2014	216	1878	1453	180	21	3748
2016	413	1792	1145	94	303	3747
2018	157	1518	1548	78	446	3747
2020	0	2044	1217	53	434	3748

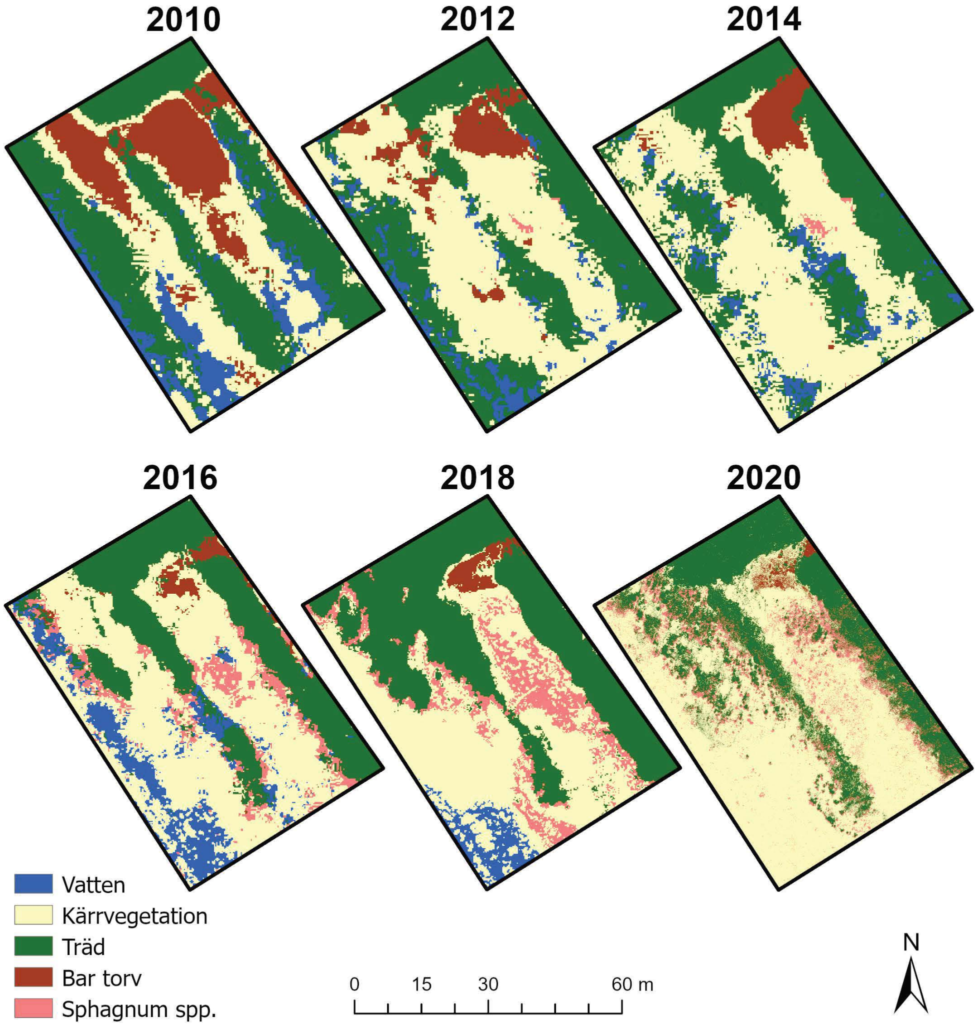


Figure 9: Vegetation development in Toftmossen from 2010 to 2020 by GIS analysis based on orthophotos from Lantmäteriet and classified in ArcMap 10.6 using ISO Cluster Supervised Classification; pixel size 0.5 m (2010 and 2012), 0.25 m (2014, 2016 and 2018) and 0.10 m (2020).

In spring 2021, 10 m^3 of *Sphagnum* for cultivation at Ekebymossen was brought out (figure 10 and 11). Here we will monitor in future projects, how fast the dense packed *Sphagnum* site will terrestrialise the water surface. This will also give us a measure if compacted *Sphagnum* mats are growing faster than “loosely” spread *Sphagnum*.

Figure 10: Internship student Leon spreading the peat mosses at Ekebymossen

Figure 11: A caterpillar compacting the peat mosses at Ekebymossen

Water analyses

Water quality changed from high to low concentrations for many substances (figure 12). However, the concentration of nitrogen still varies. The watercolour has changed visibly from quite brownish immediately after rewetting to a clearer water.

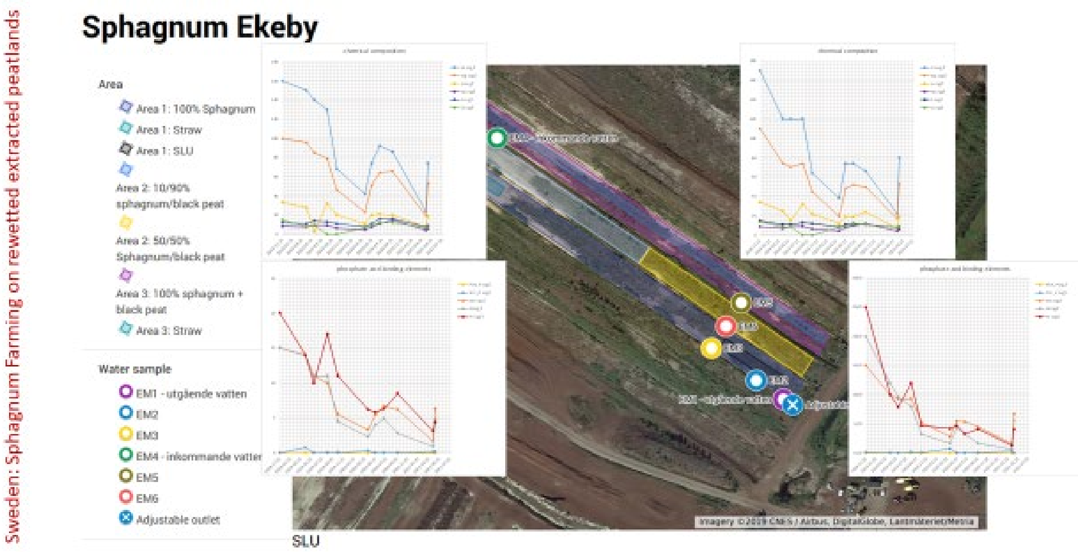


Figure 12: Study site Ekebymossen with research set up, points for water sampling and exemplary results for the development of the water quality between November 2018 and April 2021.

Sphagnum as substrate for growing media
The plant cultivation experiment showed that *Sphagnum* could become a competitive substrate for plant cultivation. Most of the plants (Basil and Tagetes) grown in the pots with *Sphagnum* were similar to the plants grown in the conventional substrates (white peat).

During the project time, two student apprentices where helping in the field and in the lab. Both are also evaluating a fraction of the massive amount of data for their bachelor and master theses.

Slutsatser

We deeply acknowledge the financial support of SLF and the peat industry, who made it possible to implement *Sphagnum* Farming after peatland rewetting for the first time in Sweden. Ekebymossen started to develop as a showroom for many stakeholders. Here we can show that *Sphagnum* Farming can become a climate-smart and productive land after-use alternative to forestry. Other peat producer companies showed interest to apply *Sphagnum* Farming.
The British Broadcasting Corporation (BBC) team visited Ekebymossen for their climate-change documentary (figure 12).

Figure 12: BBC reporter Ade spreading Sphagnum at Ekebymossen

Nytta för näringen och rekommendationer

Om så är fallet, beskriv fortsättning av projektet eller vad som behövs för att tillämpa resultaten.

Sphagnum as a renewable substrate for growing media contributes to the sustainable development of terminated extracted peatlands. It also has the greatest potential to solve a future substrate need in case there is a (political) stop on peat use: *Sphagnum* has the same chemical and physical properties as peat (same starting material, only some 100 - 1000 years younger) and can thus be competitive substrate for plant cultivation. Since peat mosses can be farmed on former peat extraction areas, soil manufacturers and horticultural industry can secure infrastructure and employment options in economically weak rural areas. This contributes to the industry also having increased durability, and to the product becoming more accepted by customers. Soil producers are in need of large amounts of uniform material for growing media and cultivated *Sphagnum* has many good properties similar to peat, something that is difficult to achieve with other alternatives. *Sphagnum* is already on the market today (but not in Sweden) and the soil manufacturers are seeing a sharp increase in demand. Introducing large-scale cultivation of renewable raw materials and estimating potential emissions or uptake of greenhouse gases after rewetting of extracted peatlands are important knowledge that gives Sweden the opportunity to report the right emissions from these places in the national climate reporting and at an international level. This quality will only be achieved with long-term projects. *Sphagnum* Farming should be considered in the after-use plan alongside other alternatives such as forestry. Climate-smart farming technologies should be investigated in future projects.

Referenser

Referenser som är citerade i rapporten inklusive referenser till tidigare stiftelsefinansierade projekt.

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Del 3: Resultatförmedling

Ange resultatförmedling av projektet, inklusive titel, referens, datum, författare/talare, och länk till presentation eller publikation om tillämpligt. Planerade publiceringar (med preliminära titlar) ska ingå i tabellen. Ytterligare rader kan läggas till i tabellen.

Vetenskapliga publiceringar	**Jordan et al. (2022): Swedish Sphagnum Farming for climate-smart restoration of extracted peatlands (journals in focus: Ecological Restoration or Mires and Peat)**
	Weber and Jordan (2022): Rewetting, paludiculture and afforestation as after-uses for an extracted peatland in nemo-boreal Sweden – An ecosystem service assessment (journals in focus: Ecological Restoration or Mires and Peat)
Övriga publiceringar	**Jordan et al. (2021): Sphagnum mosses from rewetted extracted peatlands for growing media. Poster at International Peatland Congress 2021, Tallinn/Estonia.**
	Weber et al. (2021): Early stages of revegetation after two years of rewetting an extracted peatland in Sweden. Poster at International Peatland Congress 2021, Tallinn/Estonia.
	Kling, M. & Jordan, S. (2020): Vitmossodlingen igång och utvidgad. Tidningen Svensk Torv 1, 4-5. kling_m_et_al_201217.pdf (slu.se)
	Jordan, S. (2020): Rewetting of extracted peatlands – Swedish field experiment for Sphagnum Farming started Paludiculture Newsletter 2020_01 English.pdf (moorwissen.de)
	Kling, M. & Jordan, S. (2019): Sphagnum Farming in Focus. In: Peatlands International, 4, ISSN 1455-8491, International Peatland Society, Jyväskylä, 20-22.
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	Jordan et al. (2018): Climate-smart Sphagnum in rewetted extracted peatlands in Sweden. Poster at Symposium 50 years International Peatland Society, Rotterdam/Netherlands.
	Jordan et al. (2018): Climate-smart Sphagnum in rewetted extracted peatlands in Sweden. Poster at WETSCAPES – Workshop PEAT UNDER WATER, Malchin/Germany.

Muntlig kommunikation	**BBC (Climate change: Ade on the frontline)** Peatlands in Sweden - BBC Teach
	Sphagnum Farming research station at Ekeby Mosse as showroom for excursions and presentations
	Invited speaker at World Soil Day 2019 and Peatlands Day 2021
	Weber et al. (2021): Early stages of revegetation after two years of rewetting an extracted peatland in Sweden. Oral presentation at RRR2021 virtual conference ”Renewable Resources from Wet and Rewetted Peatlands”, 3rd International Conference on the Utilisation of Wetland Plants. Greifswald. RRR2021_proceedings.pdf (moorwissen.de)
Studentarbete	**Eva Weber (Master Thesis Nov. 2021): Assessing after-uses for extracted peatlands in nemo-boreal Sweden – An ecosystem service approach**
	Leon Schröder (Bachelor Thesis Oct. 2021): Bilanzierung der sommerlichen Kohlenstoffflüsse nach Wiedervernässung eines ehemaligen Torfabbaugebietes in Schweden
Övrigt	**2 student apprentices worked at Ekebymossen**
	Parlamentarians (riksdagsledamöter) and Örebros governor (lantshövding) were on a visit at Ekebymossen