LIFE RESTORE PROJECT
INTERNATIONAL CLOSING CONFERENCE

SUSTAINABLE MANAGEMENT OF DEGRADED PEATLANDS AND CLIMATE CHANGE MITIGATION

June 13-14, 2019
Academic Center for Natural Sciences of the University of Latvia
Jelgavas iela 1, Rīga

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Sustainable and responsible management and re-use of degraded peatlands in Latvia
LIFE REstore
LIFE14 CCM/LV/001103

September 1, 2015 – August 30, 2019
Beneficiaries:
- Nature Conservation Agency of Latvia / **www.daba.gov.lv**
- Latvian State Forest Research Institute "Silava" / **www.silava.lv**
- Latvian Peat Association / **www.peat.lv**
- Association "Baltic Coasts" / **www.baltijaskrasti.lv**

Website: **restore.daba.gov.lv**
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liferestore

Compiled by **Anda Zālmane.**
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Table of contents

INTRODUCTION

Welcome!

We would like to highlight the importance of LIFE REstore project whereunder a number of assessments were carried out for the first time in Latvia, including the analysis on how greenhouse gas emissions from differently managed peatlands affect the climate change and evaluation of decision-making support tools. Moreover, the project covers the development of solutions for responsible management and sustainable use of peatlands affected by peat extraction.

This conference will provide you with knowledge and experience in three main topics:

- The influence of differently managed peatlands on climate change mitigation; development of national GHG emission factors;
- After-use of peatlands affected by peat extraction; recommendations for their sustainable management;
- Inclusion of assessment of ecosystem services in the planning of future use of degraded peatlands.

We are really pleased that representatives not only from Latvia, but also from the European Commission, International Peat Society, Lithuania, Estonia, the United Kingdom and Spain are participating in the conference, offering their views on these topical issues.

We hope that the conference will provide valuable information, knowledge and new insights into the important role of mires and peatlands in nature, climate change mitigation and in the economy.

Project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" – LIFE REstore – is the first project of European Commission LIFE programme Climate Action sub-programme in Latvia. It is implemented by Nature Conservation Agency of Latvia.

Yours sincerely, **Ieva Saleniece**,
Manager of LIFE REstore project,
Nature Conservation Agency of Latvia

CONFERENCE PLAN

CONFERENCE WILL BE HELD OVER TWO DAYS

June 13, 2019 – Thursday

8.30 – 17.30

Academic Center for Natural Sciences
of the University of Latvia, Jelgavas street 1, Riga –
Magnum, Sinistrum, Dextrum auditoriums

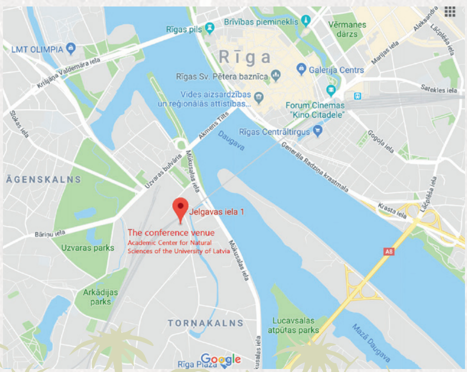
Presentations, pannel discussion, poster sessions,
demonstrations of LIFE REstore
database and optimisation model etc.

June 14, 2019 - Friday

8.30 - 14.30

Kaigu Mire (Jelgava Municipality);
starting at Academic Center for
Natural Sciences of the University of Latvia,
Jelgavas street 1, Riga

Field trip to LIFE REstore demo sites where after-use
measures of degraded peatlands were implemented;
demonstration of GHG emission measurements



JUNE 13, 2019 - CONFERENCE DAY 1

CONFERENCE PROGRAM

8.30	Registration
9.00	**Significance of peatland management in the context of nature conservation.** Juris Jātnieks, Director General of Nature Conservation Agency of Latvia
9.10	**The contribution of LIFE programme in Latvia.** Ilona Mendziņa, Ministry of Environmental Protection and Regional Development, Deputy Director of Department of Nature Protection
9.20	**LIFE REstore – the first climate project of EU LIFE programme in Latvia. Framework and achievements.** Ieva Saleniece, LIFE REstore Manager, Nature Conservation Agency of Latvia
Session 1 – Impact of Peatlands on Climate Change Mitigation	
9.40	**Objectives of EU LULUCF sector for climate change mitigation, and their achievement** (video-conference). Giacomo Grassi, European Commission, JRC
10.20	**The contribution of LIFE REstore project in development and implementation of climate policy.** Ilze Prūse, Ministry of Environmental Protection and Regional Development, Director of Climate Change Department
10.35	**The contribution of LIFE REstore project to improvement of activity data for accounting greenhouse gas emissions due to management of wetlands.** Andis Lazdiņš, LIFE REstore Expert, Senior Researcher at Latvian State Forest Research Institute "Silava"
10.55	Coffee break, poster session, LIFE REstore short films, demonstration of database of peatlands affected by peat extraction and optimisation model
11.25	**Results of GHG emission measurements in differently managed peatlands in Latvia – the basis for new national GHG emission factors.** Ainārs Lupiķis, LIFE REstore Expert, Researcher at Latvian State Forest Research Institute "Silava"
11.55	**Paris 2015 and peatlands – vision and reality. Experience in Europe with different after-uses of degraded peatlands during last decades.** Bernd Hofer, International Peat Society, Chair of Peatland and Environment Commission
12.25	**Panel Discussion: LULUCF sector, national GHG emission factors**
12.50	LUNCH

Session 2 – Management recommendations for peatlands affected by peat extraction	
13.30	**Conditions of peatland management in Latvia after peat extraction. Recultivation types of degraded peatlands and recommendations for sustainable management.** Ingrīda Krīgere, LIFE REstore Expert, Member of the Board of Latvian Peat Association
13.50	**Importance of ecosystem services provided by Latvian mires.** Andris Širovs, Director of Nature Conservation Agency, Pierīga Regional Administration
14.05	**LIFE REstore developed optimisation model for sustainable management of territories affected by peat extraction.** Elina Konstantinova, LIFE REstore Expert, Association "Baltic Coasts"
14.20	**Functional land management model – a tool for planning of sustainable land management policy.** Aleksejs Nipers, Senior Researcher at the Institute of Economics and Regional Development, Latvia University of Life Sciences and Technologies
14.40	**Linking the LIFE REstore recommendations for after-use of degraded peatlands with Guidelines for sustainable use of peat.** Kristīne Gāga, Ministry of Environmental Protection and Regional Development, Senior Expert at Department of Environmental Protection
14.50	**Responsible peatland management in Latvia.** Uldis Ameriks, Chairman of the Board of "Laflora" Ltd.
15.05	Coffee break, poster session, LIFE REstore short films, demonstration of database of peatlands affected by peat extraction and optimisation model
15.35	**Peatland restoration at a national scale: Scotland's Peatland ACTION project.** Emily Taylor, Peatland ACTION Project Officer, Crichton Carbon Centre
15.55	**Pennine PeatLIFE - geographically appropriate Sphagnum-based bog restoration techniques.** Paul Leadbitter, Pennine PeatLIFE Manager
16.15	**Peatland renaturalization experience in Latvia and results of vegetation studies in LIFE REstore project.** Māra Pakalne, LIFE REstore Expert, the University of Latvia, Association "Baltic Coasts"
16.30	**Wise use of degraded peatlands – tool to mitigate climate change.** Nerijus Zableckis, Projects Manager of Lithuania Fund for Nature, LIFE Peat Restore
16.50	**Experiences and challenges of restoration and use of peatlands in Estonia.** Juri-Ott Salm, Project Coordinator, Estonian Fund for Nature, LIFE Mires Estonia
17.10	Closing of the conference

* Vegetarian options of menus will be available for lunch.

** Conference program may be revised.

POSTER SESSION

June 13, 2019 at 10.55-11.25
and 15.05-15.35

Sinistrum Auditorium of Academic Center for Natural Sciences of the University of Latvia

LIFE RESTORE PROJECT POSTERS

- **Five demonstration areas in the project - evaluation of impact on the GHG emissions.** Andis Lazdiņš, Aldis Butlers, Ainārs Lupiķis, Arta Bārdule
- **Inventory of territories affected by peat extraction and its results.** Juris Pētersons, Andis Lazdiņš
- **LIFE REstore project open access database and its application.** Ieva Bukovska
- **Three-dimensional hydrogeological modelling in demonstration sites in Lauga and Ķemeri Bogs.** Oļģerts Aleksāns, Juris Pētersons
- **After-use of post-harvested peatlands and restoration of the raised bog: assessing the economic value of ecosystem services.** Aija Persevica, Elina Konstantinova, Liga Brunina
- **Establishment of Highbush Blueberry *Vaccinium corymbosum* and Large Cranberry *Vaccinium macrocarpon* plantations in peatlands degraded by peat extraction.** Juris Pētersons
- **Peatland recultivation - a case study of a commercial tree plantation in a former peat extraction area.** Dagnija Lazdiņa, Santa Neimane, Santa Celma, Vita Krēsliņa, Kārlis Dūmiņš, Toms Arturs Štāls, Modris Okmanis, Gints Spalva, Andis Lazdiņš, Kristaps Makovskis
- **Renaturalization (Sphagnum Planting) of degraded peatland in LIFE REstore demo site at Ķemeri National Park.** Agnese Rudusāne, Māra Pakalne, Juris Pētersons
- **Stabilization of the hydrological regime of the Višezers Lake at LIFE REstore demo site in Lauga Mire.** Agnese Rudusāne, Juris Pētersons
- **A type of peatland recultivation: reforesting.** Dagnija Lazdiņa, Ingrīda Krīgere, Inārs Dreimanis, Laimdota Kalniņa, Andis Lazdiņš
- **A type of peatland recultivation: establishing arable land for the cultivation of arable crops.** Ingrīda Krīgere, Inārs Dreimanis, Dace Siliņa, Laimdota Kalniņa, Andis Lazdiņš
- **A type of peatland recultivation: cultivation of large cranberries.** Ingrīda Krīgere, Inārs Dreimanis, Dace Siliņa, Laimdota Kalniņa, Andis Lazdiņš
- **A type of peatland recultivation: cultivation of highbush blueberries and lowbush blueberries.** Ingrīda Krīgere, Dace Siliņa, Inārs Dreimanis, Laimdota Kalniņa, Andis Lazdiņš

- **A type of peatland recultivation: paludicultures.** Ingrīda Krīgere, Laimdota Kalniņa, Ilze Ozola, Andis Lazdiņš
- **A type of peatland recultivation: renaturalisation.** Ingrīda Krīgere, Laimdota Kalniņa, Inārs Dreimanis, Māra Pakalne, Andis Lazdiņš
- **A type of peatland recultivation: establishing of water reservoirs.** Ingrīda Krīgere, Inārs Dreimanis, Laimdota Kalniņa, Andis Lazdiņš
- **Type of peatland recultivation: perennial grasslands.** Ingrīda Krīgere, Inārs Dreimanis, Laimdota Kalniņa, Dace Siliņa, Andis Lazdiņš
- **LIFE REstore project: summary.** Ieva Saleniece, Anda Zālmane

OTHER POSTERS

- **Alternative use of peat.** Edgars Ameriks.
- **Characteristics of deposit and water chemical composition and pollution from Lauga bog.** Jānis Dreimanis, Laimdota Kalniņa, Līga Paparde
- **Cultivation of large cranberries in peat bog in Latvia.** Līga Vilka, Dace Siliņa
- **EU protected mire habitat mapping and quality assessment by airborne remote sensing data.** Rūta Abaja, Dainis Jakovels, Jevgēnijs Fiļipovs, Juris Taškovs, Gatis Eriņš
- **Evidence of climate changes in Lubāns wetland deposits: example of Sūļagols and Asne site.** Līga Paparde, Laimdota Kalniņa, Jānis Dreimanis, Aija Ceriņa
- **Innovative method of greenhouse gas emission assessment for peatlands based on remote sensing data and GEST analysis.** Rūta Abaja, Jevgēnijs Fiļipovs, Līga Strazdiņa, Māra Pakalne, Dainis Jakovels
- **Mapping of ecosystems and their services – Latvian coastal ecosystems case study.** Inga Hoņavko
- **Nature Census in Latvia.** Irisa Mukāne, Gita Strode, Anita Namatēva
- **Peatland restoration for carbon sequestration and climate change mitigation in three Latvian peatlands – LIFE project "Peat Restore".** Māra Pakalne, Līga Strazdiņa, Agnese Priede, Krišjānis Libauers
- **Restoration experiment of *Sphagnum magellanicum* in the Pyrenean mires.** Jordina Gili, Aaron Pérez Haase, Jaume Espuny
- **Spontaneous revegetation in harvested peatlands in Latvia provides indicators for assessing success of rehabilitation.** Agnese Priede, Anna Mežaka
- **The importance of geological studies for the assessment of degraded peatlands.** Laimdota Kalniņa, Ingrīda Krīgere, Jānis Dreimanis, Agnese Rudusāne, Līga Paparde, Reinis Bitenieks
- **Ecosystems services economic valuation: case study in Latvia.** Aija Persevica, Elina Konstantinova, Liga Brunina

DEMONSTRATION OF DATABASE OF PEATLANDS AFFECTED BY PEAT EXTRACTION

June 13, 2019
at 10.55-11.25 and 15.05-15.35

Sinistrum Auditorium of Academic Center for Natural Sciences of the University of Latvia

Peatlands affected by peat extraction in Latvia were inventoried during LIFE REstore project, and publicly accessible database was created in nature data management system "Ozols" https://restore.daba.gov.lv/public/lat/datu_baze1/.

Conference participants are invited to access the database through the use of touch screens.

DEMONSTRATION OF OPTIMISATION MODEL FOR SUSTAINABLE MANAGEMENT OF PEATLANDS AFFECTED BY PEAT EXTRACTION

June 13, 2019
at 10.55-11.25 and 15.05-15.35

Sinistrum Auditorium of Academic Center for Natural Sciences of the University of Latvia

The optimisation model prepared during the LIFE REstore project is a decision-making support tool that allows planning of further management in territories after the completion of peat extraction. It provides recommendations for after-use types suitable for a particular area, allows to evaluate their implementation (calculation of necessary investments), and shows the environmental, climate and economic benefits. Optimisation model is available at:

https://restore.daba.gov.lv/public/lat/optimizacijas_modelis1/

Conference participants are invited to access the optimisation model through the use of touch screens.

DEMONSTRATION OF LIFE RESTORE SHORT FILMS

June 13, 2019
between the conference sessions

Magnum Auditorium of Academic Center
for Natural Sciences of the University of Latvia;
screens near the Auditorium

LIFE REstore invites to watch the documentary short films on the main activities and results of the project:

- About the LIFE REstore project
- Inventory of peatlands affected by peat extraction in Latvia
- After-use of degraded peatlands: planting of Sphagnum mosses
- After-use of degraded peatlands: renaturalization in Lauga Mire
- LIFE REstore database of peatlands affected by peat extraction
- After-use of degraded peatlands: afforestation
- After-use of degraded peatlands: cultivation of berries
- About peat extraction sector in Latvia
- Measurements of greenhouse gas emissions in managed peatlands in Latvia
- Optimisation model of degraded peatlands sustainable management; inclusion of ecosystem services assessment in the decisions on after-use of degraded peatlands

PEAT SCULPTURE "HUMAN AND NATURE"

June 13, 2019
Permanently – a gift to the University of Latvia

Main stairs of Academic Center for
Natural Sciences of the University of Latvia

Peat researcher and artist Edgars Ameriks will unveil the peat sculpture "Human and Nature" and present it to the Academic Center for Natural Sciences of the University of Latvia.

PHOTOGRAPHY EXHIBITION "RESTORING PEATLANDS FOR CLIMATE"

June 13, 2019
throughout the conference

Ground floor, Academic Center for
Natural Sciences of the University of Latvia

LIFE Peat Restore project photography exhibition "Restoring Peatlands for Climate" invites you to learn about mires, their role in nature, as well as mire restoration and research in five European countries.

JUNE 14, 2019 - CONFERENCE DAY 2

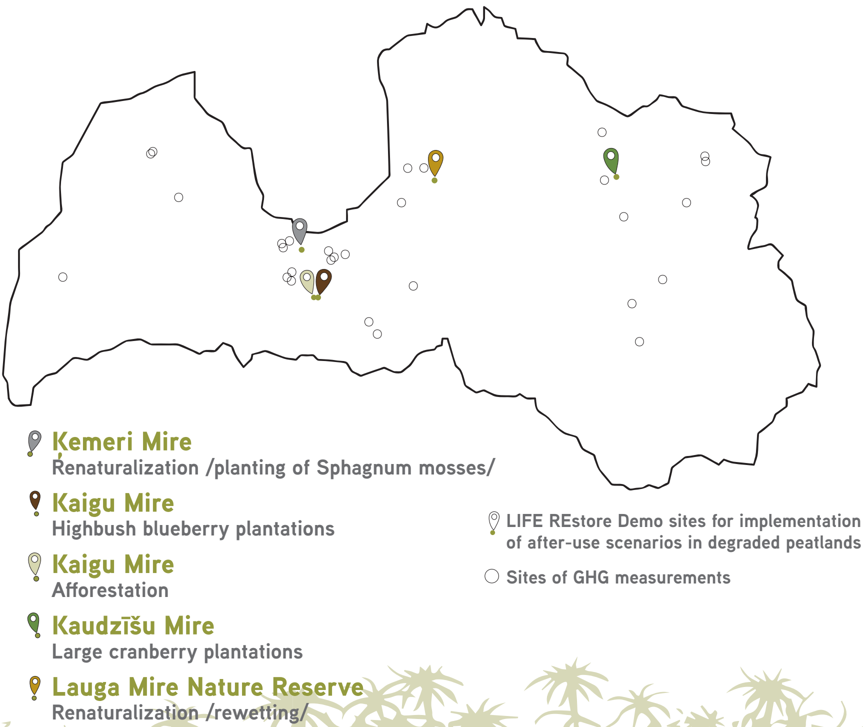
FIELD TRIP TO LIFE RESTORE DEMONSTRATION SITES

June 14, 2019 at 8.20

We invite you to use transport provided by LIFE REstore – from Academic Center for Natural Sciences of the University of Latvia, Jelgavas Street 1, Rīga, at 8.20.

Field trip to LIFE REstore demo sites where after-use types of peatlands affected by peat extraction were implemented.

8.30	Departure from Rīga to Jelgava municipality
10.00	Introduction of responsible peatland management in Kaigu Mire, at peat extraction and processing company "Laflora" Ltd.
10.30	Visit to LIFE REstore afforestation demo site
11.30	Demonstration of greenhouse gas emission measurement process
12.00	Picnic lunch
12.30	Visit to LIFE REstore highbush blueberry plantation demo site
13.00	Departure to Rīga (return at 14.30)



LIFE RESTORE AFFORESTATION DEMO SITE

Afforestation as an after-use type of peatland was introduced in Kaigu Mire, in cooperation with "Laflora" Ltd.. Instead of a long-term afforestation, the creation of short rotation woodland was tested within this scenario. Plantation in an area of more than 9 ha was established, aimed at the production of wood biomass.

LIFE REstore project tested the most effective and appropriate tree species (silver birch *Betula pendula,* black alder *Alnus glutinosa,* Scots pine *Pinus sylvestris,* poplar *Populus* spp. v. *Vesten*), and their combinations for afforestation of degraded peatlands, focusing on economically advantageous short rotation woody crops. Also the optimal concentration of biological fertilizer – wood ash – for the different tree species was tested. GHG emissions were measured, allowing estimation of climate impact of this recultivation scenario.

Afforestation is an effective after-use type from the point of view of climate change mitigation. Application of wood ash is important at an early stage of tree growth, when trees do not yet attract carbon from the atmosphere. At the same time, this significantly reduces greenhouse gas emissions from soil. As trees grow, they capture and store carbon in timber, thus compensating for GHG emissions from soil. This effect increases with growing of short rotation woody crops, producing wood biomass.

LIFE RESTORE HIGHBUSH BLUEBERRY PLANTATION DEMO SITE

Highbush blueberry plantations were established in LIFE REstore project demo site in Kaigu Mire (Jelgava municipality). Three sample plots were established in an area of 4.2 hectares, in cooperation with "Arosa-R" Ltd., and highbush blueberries of different varieties were planted.

The best practices of highbush blueberry cultivation experience in Latvia were analysed and applied for the establishment of berry plantations, aimed at GHG emission reduction from degraded peatland. During the implementation of this after-use scenario, exact changes of GHG emissions were recorded. The obtained measurement results allow to evaluate the establishment of highbush blueberry plantations also from the aspect of climate change mitigation.

LIFE RESTORE DEMONSTRATION: MEASUREMENTS OF GHG EMISSIONS IN MANAGED PEATLANDS

In the framework of LIFE REstore project, GHG emissions were measured within a two year period – from December 2016 to December 2018. Using closed chamber method, gas samples were obtained and analysed in a laboratory for the most significant GHG content (carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)); their changes over the time were assessed. Samples were taken in 41 site in the whole territory of Latvia in organic soils, differing with the type of land use: active peat extraction sites, post-harvested peatlands without vegetation, post-harvested peatlands with vegetation of grasses and dwarf shrubs, cropland (cereals, vegetables), perennial grasslands, conifer and deciduous woodlands, as well as transitional mires and raised bogs which are little influenced by economic activity. In framework of LIFE REstore project, GHG emissions were measured by OÜ "Severitas" and the University of Tartu (Estonia), in cooperation with Latvian State Forest Research Institute "Silava".

ABOUT LIFE RESTORE PROJECT

The aim of LIFE REstore is to develop recommendations for sustainable management of peatlands after peat extraction, by balancing environmental, climate and economic aspects.

The main activities of LIFE REstore project were:

- Inventory of peatlands degraded by peat extraction in Latvia; development of a publicly available database;
- Measurements of greenhouse gas (GHG) emissions in managed peatlands; development of national GHG emission factors;
- Assessment of ecosystem services in degraded peatlands; determination of their economic value;
- Testing of after-use scenarios in project demo sites;
- Development of sustainable management optimisation model for degraded peatlands;
- Development of recommendations for sustainable management of degraded peatlands.

ABSTRACTS OF THE CONFERENCE PRESENTATIONS

SIGNIFICANCE OF PEATLAND MANAGEMENT IN THE CONTEXT OF NATURE CONSERVATION

Juris Jātnieks
Nature Conservation Agency of Latvia
juris.jatnieks@daba.gov.lv

The value of mires from the aspect of ecosystem services

Latvia is a country rich in natural resources and mires are an essential element of its landscape. Undisturbed mires have the highest value in terms of the ecosystem services. These peatlands have an essential role in providing regulating services such as climate regulation through carbon storage and sequestration and regulation of water quality through filtration of pollutants.

Peatlands provide provisioning services such as berries and mushrooms, raw materials, water, biomass–based energy sources. As distinct natural landscapes, peatlands have a high aesthetic value and provide a location for recreation, nature tourism and bird watching.

By restoring wetland ecosystems, it is possible to increase the volume of accumulated carbon dioxide, thereby "withdrawing" it from the atmosphere and thus reducing the impact on climate change. It is most important to preserve and restore the natural functions of mires which help to keep mire ecosystems and the associated biodiversity alive.

While the focus on provisioning services has often led to the degradation of peatland ecosystems, the recognition of services that peatlands provide to people can serve as a strong motivation for restoration.

Experience and knowledge in the wetland management

Over the years we have acquired a substantial experience and knowledge in habitat restoration and management based on our practical experience and nature protection planning.

First restoration works of a raised bog hydrological regime were carried out in 1997 in Teiči Bog - one of the largest ecosystems of its kind in the Baltic area - by constructing 42 wooden dams on the ditches to prevent the drainage impact on the bog ecosystem. The experience of the Teiči Nature Reserve in restoring the hydrological regime of mires has been either replicated or at least referred to by almost all other LIFE-Nature projects that have envisaged this type of action.

In the next years, the construction of dams on ditches was carried out on a larger scale both in Teiči Mire and in Lubāna Wetland. In 2006, for the first time, targeted habitat restoration of the cut-away peatland was carried out: water level was restored in a post-harvesting area on the edge of the Great Ķemeri Mire.

Guidelines for the conservation, management and restoration of protected habitats in Latvia have been developed from 2013 to 2016 under the LIFE programme project "National Conservation and Management Programme for Natura 2000 Sites" and were implemented by the Nature Conservation Agency of Latvia.

The guidelines provide comprehensive recommendations for the conservation, management and restoration of natural habitats, including peatlands and will form the basis for solving the future nature conservation challenges.

The Nature Conservation Agency has successfully completed six projects under the LIFE programme and four projects are currently being implemented. Every implemented project provides a further insight into complicated issues of the sustainable nature management.

The project "Sustainable and Responsible Management and Re-use of Degraded Peatlands" (LIFE REstore) is the first climate change mitigation project in Latvia implemented by the Nature Conservation Agency and associated partners, providing a decision support system for responsible and sustainable re-use and management of degraded peatlands in Latvia.

LIFE RESTORE – THE FIRST CLIMATE PROJECT OF EU LIFE PROGRAMME IN LATVIA. FRAMEWORK AND ACHIEVEMENTS

Ieva Saleniece
Nature Conservation Agency of Latvia, LIFE REstore project
ieva.saleniece@daba.gov.lv

Keywords: REstore, degraded extracted peatlands, decision making tool, national GHG emission factors.

Introduction

The project "Sustainable and Responsible Management and Re-use of Degraded Peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103) is the first climate change mitigation project in Latvia which is financed from the European Union LIFE Programme. The LIFE REstore project is being implemented by Nature Conservation Agency in partnership with Latvian Peat Association, Latvian State Forest Research Institute "Silava", and the association "Baltic Coasts". The project's duration is from 1 September 2015 to 30 August 2019.

There are abandoned extracted peatlands in Latvia which have not naturally recovered for decades, therefore a purposeful and sustainable management should be planned. It is also important to select the most appropriate reclamation method so that the environmental, climate and economical aspects are all well balanced.

The main objective of the LIFE REstore project was to develop recommendations for the sustainable management of degraded extracted peatlands in Latvia.

The following tasks were set in order to achieve this objective:

1. a geological survey and vegetation inventory in degraded and extracted peatlands in Latvia;
2. development of national greenhouse gas emission (GHG) factors and approval of an emission accounting method based on analysis of GHG samples collected in field;
3. development of a decision-making tool for the planning of responsible management of degraded extracted peatlands, which would ensure a balance between the biodiversity conservation, economic benefits, and the long term reduction of GHG emissions in Latvia;
4. support the policy makers by providing information, recommendations and methods for the sustainable use of degraded extracted peatlands.

Results

About 50 thousand hectares were identified by the LIFE REstore project experts as peatlands which are degraded by the peat extraction. For about 18 thousand of them, a decision on their further use must be taken – reclamation measures should be carried out as soon as possible, or first the remaining peat resources could be used and then the reclamation applied.

The elaborated national GHG emission factors for certain organic soils, as well as the approved GHG emission measurement methodology will be an essential component in the planning and implementation of the climate policy. The LIFE REstore results, for the first time, provide objective information about GHG emissions from the managed organic soils in Latvia and will serve as a core of the knowledge around which data from other countries will aggregate in the future, thus forming a comparable and widely applicable emissions accounting system for organic soils.

The Optimisation model for sustainable management of degraded peatlands will be an important support tool for landowners planning the sustainable management of their territories and choosing the most appropriate after-use type of peatlands. The model allows comparing and evaluating different reclamation scenarios and thus provides a basis for sustainable and well-considered decisions.

The completed peatland inventory and developed reclamation recommendations are an important practical addition to the National Peat Strategy currently being elaborated.

By implementing reclamation measures in project demo sites, the project has reached the predefined climate change mitigation indicators. Among the tested options, the establishment of cranberry plantations and Scots pine plantations were considered to be the most efficient after-use types for climate change mitigation.

During the project lifetime, cooperation ties between the parties involved in peatland management were strengthened and, in some cases, also established. These interactions are important and must be supported also in the future. The collaboration among the Nature Conservation Agency, experts and entrepreneurs in the peat sector, as well as leading scientists of all parties involved contributed to an enhanced understanding of the interaction between nature conservation, climate change and economic development.

CONTRIBUTION OF LIFE RESTORE PROJECT TO IMPROVEMENT OF ACTIVITY DATA FOR ACCOUNTING GREENHOUSE GAS EMISSIONS DUE TO MANAGEMENT OF WETLANDS

Dr. silv. Andis Lazdiņš, Aldis Butlers, Mg. silv. Ainārs Lupiķis
Latvian State Forest Research Institute "Silava"
andis.lazdins@silava.lv, aldis.butlers@silava.lv, ainars.lupikis@silava.lv

Keywords: GHG, emissions, inventory, activity data, wetlands.

This study represents results on remote sensing-based evaluation of land use and land use changes in former and existing peat extraction areas in Latvia. The aim of the study is to elaborate an activity data set for the National GHG inventory for the wetlands remaining wetlands for peat extraction. The study provides sufficient data for application of the default emission factors for peat extraction sites and flooded lands. In application of the emission factors, abandoned peat extraction fields which are not yet afforested, flooded or rewetted, should be reported as peat extraction sites following a conservative approach. The results of this study can be used to report land use changes since 1990; however, linearised approach in calculation of the land use change may result in overestimation or underestimation of GHG emissions over certain periods of time. According to this study, the actual area of peat extraction sites is considerably bigger than currently reported in the National GHG inventory, mainly due to considerable area of abandoned peat extraction fields. Flooded lands may be significant source of emissions and should be introduced in the National GHG inventory to secure consistency of reporting. Methodology for calculation of GHG emissions from flooded lands should be also elaborated. It is also necessary to elaborate emission factors for fertile and non-fertile peat extraction sites and continue the work on separation of different soils in the inventory to increase accuracy of calculations.

The study is implemented within the scope of the EU LIFE programme project LIFE14 CCM/LV/001103 "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore).

RESULTS OF GHG EMISSION MEASUREMENTS IN DIFFERENTLY MANAGED PEATLANDS IN LATVIA – THE BASIS FOR NEW NATIONAL GHG EMISSION FACTORS

Mg. silv. Ainārs Lupiķis
Latvian State Forest Research Institute "Silava"
ainars.lupikis@silava.lv

Soil is the biggest carbon pool in terrestrial ecosystems. One third of the soil carbon is stored in peatlands, although the area of peatlands is only 3% from the area of world soils. Peatland management usually is impossible without drainage. Drainage is necessary both for a peat extraction and also to grow plants for a commercial use, but it have climate warming effect, because peat decomposition and CO_2 emissions increases after lowering of ground water level. The aim of the study is to evaluate the anthropogenic impact of peatland management with different land use type in Latvia.

We used manual closed chamber technique and air sampling to measure CO_2, CH_4 and N_2O concentrations. Air samples were collected each 20 minutes during one hour (4 samples from chamber). The size of the chamber is 0.065 m3. Transparent chambers (for photosynthesis) and EGM-5 portable CO_2 gas analyzer were used for of CO_2 ecosystem flux measurement.

In total, there was 41 sample plot, with 5 collars in sample plot. Each sample plot was measured once in a month for 2 years from December of 2016 to November of 2018. We chose 12 different land use types according to the dominant vegetation in site and 3 to 4 replicates for each site. Those land use types are – 1. peat extraction sites, 2. abandoned peat extraction sites with bare peat, 3. abandoned peat extraction sites with ground vegetation, 4. perennial grasslands, 5. croplands (cereal), 6. croplands (legumes), 7. pine forests, 8. birch forests, 9. raised bog, 10. transitional mire, 11. cranberry plantations, 12. blueberry plantations.

The results shows that the highest net CO2-C emissions is in agricultural lands, with CO_2-C emissions from 3.3 tons CO_2C ha^{1} annually in grasslands to 3.7 tons CO_2C ha^{1} annually for legumes (table 1), but the smallest net emissions is in coniferous and deciduous forests and cranberry plantations – 1.0 tons CO_2C ha^{1} annually, 1.1 tons CO_2C ha^{1} annually and 1.2 tons CO_2C ha^{1} annually. Unexpectedly high CO_2-C emissions were measured in raised and transitional bog sites. The explanation for this is unclear, but it may be related with anthropogenic pressure on those sites (those sites are located near peat extraction sites or near the highways and regional roads), but this hypothesis can't be approved on the basis of measurements in this project.

The biggest source of methane is raised and transitional bog sites with emissions of 135 kg CH_4C ha^{1} annually and 384 kg CH_4C ha^{1} annually. Some sites – both types of croplands and coniferous forests were small sinks of CH_4-C. There was clear and strong correlation between ground water levels and CH4 emissions.

As it was expected, the biggest N2O emissions occurred in both types of cropland and the emissions in those sites were 8.0 kg N_2OC ha[1] annually and 4.5 kg N_2OC ha[1] annually for cereal crops and legumes. Some N2O emissions (1.4 kg N_2OC ha[1]) were also observed in transitional bog sites, but more than 70% of all N2O emissions in transitional bogs occurred during March of 2017. In all of the other sites N2O emissions were negligible and monthly emissions very often was negative.

If the total net emissions in CO_2 equivalents for all three measured greenhouse gases is considered, the biggest impact was observed in transitional bogs, with total emissions – 20.0 ± 10.8 tons CO_2 eq. annually (Figure 1). Such a huge total climate impact is due to the extremely high CH_4 emissions from transitional bogs. Large total net emissions were observed also in grasslands and both types of croplands, where total impact to climate ranges from 17.1 tons CO_2 eq. annually to 19.2 tons CO_2 eq. annually. But the smallest impact is for forest sites and cranberry plantations.

Table 1. Mean annual CO2-C, CH4-C and N2O-N emissions in all land use types.

Land-use type	Mean net emissions			Confidence interval (α=0.05)		
	CO2-C tons ha1 annually	CH4-C kg ha1 annually	N2O-N kg ha1 annually	CO2-C tons ha-1 annually	CH4-C kg ha1 annually	N2O-N kg ha1 annually
1	1.8	10.7	0.4	0.5	14.5	0.7
2	1.7	0.7	0.2	0.4	1.0	0.3
3	1.8	26.4	0.0	0.9	33.9	0.2
4	4.4	57.8	0.3	1.2	72.1	0.4
5	4.2	-0.4	8.0	1.6	0.8	6.1
6	4.1	-1.3	4.5	2.1	0.5	2.5
7	1.0	-1.4	0.0	1.1	1.3	0.2
8	1.2	24.9	0.6	1.1	37.3	0.6
9	1.3	135.0	0.2	0.8	155.4	0.5
10	1.8	383.8	1.4	0.9	216.4	0.8
11	1.5	24.0	0.9	1.6	30.5	1.4
12	1.2	5.9	0.2	1.2	8.3	0.4

We can conclude that afforestation and establishment of cranberry plantations in former peat extraction sites have the potential to reduce soil GHG emissions. The worst scenario is to use peatlands for conventional agriculture. The use of peatlands for agriculture must be avoided and it is important to change management practices from agriculture to other land use types.

The results highlighted necessity to do further studies in undrained peatlands which are relatively untouched by anthropogenic use – raised and transitional bogs, as we got an unexpectedly high CO_2 emissions in those sites. Currently, there are no answers for such a high CO_2 emissions in those sites.

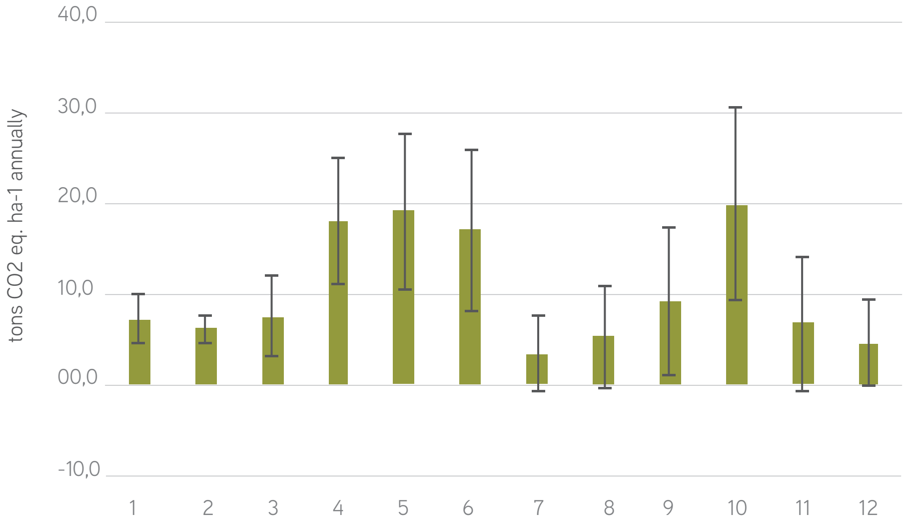


Figure 1. Total net emissions in CO2 equivalents for all three greenhouse gases.

The study is implemented within the scope of the EU LIFE programme project LIFE14 CCM/LV/001103 "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore).

PARIS 2015 AND PEATLANDS – VISION AND REALITY. EXPERIENCE IN EUROPE WITH DIFFERENT AFTER-USES OF DEGRADED PEATLANDS DURING LAST DECADES

Bernd Hofer
Hofer & Pautz GbR, Germany
hofer@hofer-pautz.de

Following the Paris Declaration from 2015 the greenhouse gas emissions have to be reduced until 2050 by 80% to 95% in general and that applies for peatlands and the use of peat too. A milestone of reduction by 70% is set for the year 2030. Thus, to ensure this objective, the end use of peatlands and peat has to be phased out more or less by 2050.

Looking to different examples from Germany and Europe, common developments and reduction strategies can be observed:

- EU ministers decided to cut down CO2-emissions from new cars until 2030 by 37,5%;
- German Coal Commission recommends to stop the use of energy coal by 2038 or earlier.

It is obvious that everyone who is responsible for greenhouse gas emissions from peatlands and peat is requested to develop their own strategies and solutions. Having a closer look at the distribution of emissions from different uses and geographical regions, two points are very clear: reduction of greenhouse gas emissions from peatlands and peat will not fulfil the Paris agreement without

- stopping of draining peatlands for agricultural and forestry use (>80%)
- stopping the emissions from tropical peatlands (50% - 70% depending on the source)

Changes in those two factors will require extremely long periods and enormous financial funding. Farmers and landowners have to be paid off to renounce their rights. Political decisions are necessary for those major plans.

Even if this were to happen during the next years, and the experience of two "green" ministers for agriculture and environment in Lower Saxony (2013 - 2018) show the opposite, the rewetting of these areas will take a few more decades. Last but not least, rewetted peatlands – especially peatlands under former agricultural use and rich innitrogen – are substantial methane sources and hence will still be greenhouse gas emitters for many years to come.

Summing up, the implementation of Paris declaration in relation to peatlands does not seem to be very realistic. But the smallest driver, the peat industry, can give an important contribution. It is obvious, that the volume of energy peat will decrease substantially during next the years because of the European subsidy politics. Growing media producers change their recipes by using more and more renewable materials.

On the other hand, the demand for growing media will increase significantly by 2050. The IPS study "Peat for Food and Quality of Life" from 2018 shows the relation between a growing population and wealth, and the change in diets with more vegetables and the consequences of urbanisation. The supply of world population with food is for sure an equally important challenge.

The resulting task for peat industry is the reduction of greenhouse gases to the unavoidable minimum.

The chose and planning of after-uses should take into consideration the lowest greenhouse gas emissions. During the last years the data of emissions from different after-uses and from different geographical regions were collected. Measures to reduce emissions from abandoned sites are an appropriate option to improve the greenhouse gas balance.

Next to the tasks of climate protection other objectives such as biodiversity (nature conservation, peatland rehabilitation) or social aspects, such as secure of livelihood should not be forgotten in order to create sustainable solutions that strike a balance between economic, environmental and social aspects.

CONDITIONS OF PEATLAND MANAGEMENT IN LATVIA AFTER PEAT EXTRACTION. RECULTIVATION TYPES OF DEGRADED PEATLANDS AND RECOMMENDATIONS FOR SUSTAINABLE MANAGEMENT

Ingrīda Krīgere, Laimdota Kalniņa, Inārs Dreimanis
Latvian Peat Association
peat@peat.lv

Keywords: peatland, recultivation, water bodies, after-use, greenhouse gas emissions.

Recultivation is the alignment of a territory in such a quality that allows it to be further utilized for its intended purpose.

The necessity to carry out a mineral resource's deposit recultivation, including peatlands, is the requirement by the Republic of Latvia law "On Subterranean depths". In Latvia, pursuant to the regulatory enactments following a peat extraction, several types of recultivation are possible. Their choice, in turn, depends on many variables (the political situation, the interests of the owners, market demand, etc.), and relative unvariables (terrain, remaining peat layer properties, groundwater level, etc.).

The type of restoration is determined before the extraction of peat by developing a peat extraction project. According to our experience, we can say that peat production at the extraction site happens for almost 75 years, with a changing political and economic situation over time and the planned type of restoration can change according to the owner. The type of recultivation depends on the landowner's wish and the spatial plan of the respective local government. If the extraction of peat is terminated or stopped earlier and the area is not restored and recultivation is unsuccessful, then the landowner must decide on the type of recultivation.

In such areas, before the start of recultivation, the remaining peat layer first must be assessed and whether there are no economic and economically justifiable reasons to continue the extraction of peat at the respective site and only then to recultivate the site.

In order to choose the type of recultivation, the type of peat that forms the surface of the area to be recultivated, the thickness of the remaining peat layer, the pH level of the top peat layer used, the average groundwater level, the average number of days per year when the area is flooded, the degree of peat decomposition, the composition of the sediment forming the bog base and the coverage with stumps must be assessed.

By evaluating all these aspects and conditions, the method of recultivation can be selected — foresting, establishing of berry plantations (large cranberries, bush blueberries or narrow-leaf blueberries), arable land, permanent grassland cultivation, water body establishment or development of paludiculture cultivation. By choosing the type of recultivation, according to the results of the LIFE REstore project research, it is possible to predict the impact of the respective type of restoration on GHG emissions.

It is the responsibility of the peat extractor to prepare the site in accordance with the requirements and technical solutions included in the extraction project for mineral resources, so that it can be recultivated. When the extractor has completed this work and received an act of completed recultivation measures prepared and signed by a construction committee established by the local government, the restoration has been completed. Further activities, depending on the type of recultivation, are carried out by the landowner who is also responsible for the further maintenance and cultivation of the recultivated areas.

Recultivation experience in Latvia is not developed enough, because only now the extraction of peat is ending in the bogs where it was started earlier, 70-80 years ago. Experience is beginning to develop in the ways of renaturalization and tree planting, in small areas, also in the cultivation of cranberries and blueberries.

An inventory of degraded peatlands in Latvia was one of the activities during the LIFE REstore project. Within the framework of the project, as of January 1, 2016, areas of 18,010 ha were found, where peat extraction has been discontinued or completed, but there is no data on the restoration of the territories .

The owner of the land will have to decide on the future use of such areas and how to recultivate them. In order to ensure the rational use of peat resources, the degraded peatlands, where the peat is in the necessary amount for industrial production and its extraction is economically justified, the best way for further use is peat extraction, except for peatlands in specially protected nature areas. These should be the first areas to be transferred for extraction, so that they can be restored afterwards and reduce the negative impact on climate change as soon as possible.

Activities have been implemented with the financial support of European Commission LIFE Programme and the Administration of Latvian Environmental Protection Fund, within the framework of project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103).

IMPORTANCE OF ECOSYSTEM SERVICES PROVIDED BY LATVIAN MIRES

Mg. biol., Mg. iur. Andris Širovs
Nature Conservation Agency of Latvia, Pierīga Regional Administration
andris.sirovs@daba.gov.lv

Keywords: Mire, Lauga Mire, ecosystem services, provisioning services, regulation and maintenance services, cultural services.

There are suitable conditions for mire development in Latvia, therefore mires are distributed all over its territory and cover 5% of its area.

According to the mire classification in Latvia, there are three types of mire: fens, transitional mires and raised bogs, which are different stages of the mire development[1].

Considering the wide distribution of mires in the country, mires can be considered as an integral part of Latvia's nature and landscape, which significantly contributes to the quality of life and well-being of society.

The benefits that nature provides in economy, social, cultural and other areas are called ecosystem services.

Ecosystem services are divided into three groups: provisioning services, regulation and maintenance services, and cultural services. Depending on the condition of the mire ecosystems, benefits to the society vary – the more natural and less disturbed the mire, the wider the range of ecosystem services provided to the public.

1 European Union protected habitats in Latvia. Interpretation manual (2013). Auniņš (ed.), Rīga, Latvian Fund for Nature, Ministry of Environmental Protection and Regional Development, p 320.

Lauga Mire can be used as an example of the mire ecosystem services. Here, a nature management plan was developed for the territory in the framework of the LIFE REstore project. One of the sections of this plan was devoted to the evaluation of the Lauga Mire ecosystem services.

In order to assess the services provided by mire ecosystems, it is necessary to identify the existing land uses and soil covers, to determine their area and functional quality. Then, based on the Common Classification of Ecosystem Services[2], ecosystem services and their characteristic indicators are identified.

Based on the results of the research described above, it can be concluded that following services are provided by mire ecosystems:

From the category of provisioning services, mire ecosystems provide wild plants (cranberries, cloudberries, also medical plants); beekeepers use mires for the production of heather honey. Mires produce a variety of raw materials which can be used for construction, energy, and for other purposes – timber, peat, surface and subsurface water. Mires are important for the production of sulphur-rich water, for example, in Ķemeri surroundings.

2) Mire ecosystems provide a wide range of regulatory and maintenance services. For example, various substances, such as heavy metals, are bound by mire vegetation, soil and living organisms. Mires provide water circulation in the ecosystem, and they are important for gas exchange, especially for storage of carbon dioxide which is a GHG. Plants growing in mires attract pollinators thus providing the pollination function. Mires have an impact on the quantity and quality of freshwater, for example, in mire outflowing rivers and in their downstream reaches (nesaprotu domu), as well as have a significant impact on the hydrological regime of the adjacent areas, reducing the consequences of floods.

3) When providing cultural services, mires attract visitors who explore nature both in guided tours, or individually - on swamp shoes in snowless conditions or on skis in winter, on boats and SUP boards in labyrinths of mire lakes. It is also possible to participate in bird watching events – watch birds which can be observed in mires mainly during their migration, such as geese and swans, as well as birds mostly associated with mires – wood sandpiper, European golden plover, great grey snike, and others. Sprawling landscapes of mires attract visitors with their mosaic of mire lakes and unusual, diminutive pines; they provide aesthetic enjoyment and spiritual interaction. For example, a walking trail of nearly 4 kilometres in Ķemeri Mire (Ķemeri National Park) is the most visited nature object in the entire national park, attracting around 100 000 visitors each year.

Analyzing the example of Lauga Mire, one can conclude that the most widespread category of the ecosystem services is regulation and maintenance services with

2 Common classification of ecosystem services. https://cices.eu/

3-5 various services being provided. They are followed by cultural services with 1-2 different services to the public and, finally, provisioning services –- where the number of services provided is 0-1[3]. It should be noted that mire ecosystems usually form complexes with forest, spring and freshwater ecosystems that significantly increase the number and diversity of the ecosystem services provided.

However, mire ecosystems and the services they provide are sensitive to a variety of external influences, in particular land-use change (for example, drainage of mire for peat extraction or agricultural use), pollution and eutrophication[4]. Amount, diversity and quality of the ecosystem services provided by mires are reduced by these degrading influences.

Main conclusions:

A. Mires in Latvia are widely distributed throughout the country and their total area is significant;

B. Taking into account the distribution and total area of mires in the country, a large proportion of the society benefits from mire ecosystem services;

C. Mires provide services in all categories – provisioning, regulation and maintenance, as well as cultural services;

D. Regulation and maintenance services (such as gas exchange, water cycle, climate regulation) play a key role;

E. Mire ecosystems are sensitive to degrading activities such as land-use changes, water regime changes, pollution and eutrophication. Therefore, activities aimed at restoration of degraded mires have a positive effect on mire ecosystems and, consequently, on the amount, diversity and quality of the services provided by mires.

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3 Matrix-Assessment of Ecosystem Services for Lauga Mire Nature Reserve and surrounding area. https://www.daba.gov.lv/upload/File/DAPi_apstiprin/DL_Laugas_purvs_17_pie11_2_ekosist_pakalp_novert_matrica.pdf

4 Maes J, Teller A, Erhard M, Grizzetti B, Barredo JI, Paracchini ML, Condé S, Somma F, Orgiazzi A, Jones A, Zulian A, Vallecilo S, Petersen JE, Marquardt D, Kovacevic V, Abdul Malak D, Marin AI, Czúcz B, Mauri A, Loffler P, Bastrup-Birk A, Biala K, Christiansen T, Werner B (2018) Mapping and Assessment of Ecosystems and their Services: Analytical framework for ecosystem condition. Publications office of the European Union, Luxembourg, p 42.

LIFE RESTORE DEVELOPED OPTIMISATION MODEL FOR SUSTAINABLE MANAGEMENT OF TERRITORIES AFFECTED BY PEAT EXTRACTION

Dr. paed. Aija Persevica, Dr. oec. Elina Konstantinova,
Dr. oec. Liga Brunina
Association "Baltic Coasts"
aija.persevica@baltijaskrasti.lv, elina.konstantinova@baltijaskrasti.lv,
liga.brunina@baltijaskrasti

Keywords: Sustainable management; recultivation; extracted peat fields, optimisation model.

Introduction

Peatland self-recovery after peat extraction is restricted and, without any purposeful actions, recovery of territory is disproportionately long. The extracted peat fields are not only worthless from the point of view of biodiversity, but are also large GHG emitters. Formation of peat and ecosystem functions in these areas is disturbed or destroyed. There is, however, a number of potential ways of recultivation of degraded peatlands that can provide different types of benefits - either in the form of economic activity or territory renaturalization. Each of the potential types of recultivation can deliver different types of benefits. Landowners should take the most appropriate and acceptable way of recultivation based on socio-economic, environmental and climate change mitigation criteria.

Based on the research and the results obtained, we have developed a model for sustainable use of territories affected by peat extraction that provides support for the planning of further use of degraded peatlands. This model provides information about financial, economic and environmental benefits of implementing a particular form of recultivation. The model ensures optimal information balance between GHG emission reductions, ecosystem service assessments and socio-economic aspects of land use.

Sustainable extracted peat land management has to focus on synergies between environmental and climate actions, by integrating the climate, environmental and biodiversity objectives in a responsible and sustainable management and re-use of degraded peatlands.

The Aim – developing a management tool for sustainable management of territories affected by peat extraction.

Methods

Sustainable management of degraded peatlands must be based on thoughtful use of territories and long-term planning. Management of activities related to land-use can be divided into two categories: (1) to get economic benefit and (2) to restore the natural mire function, or to transform the territory into other natural area.

The first category includes recultivation activities as (1) berry cultivation, (2) planting of trees with for energy purposes, (3) agriculture and (4) grassland cultivation.

The second group includes creation of natural areas – (1) bog renaturalisation, (2) growing of forest area (3) creation of water bodies.

Each of the above-mentioned peat field recultivation scenarios provides different types of benefits - financial profit from economic activity; diversified ecosystem services; reduction of GHG emissions.

By comparing and evaluating the ways of recultivation, it is possible to make sustainable and well-considered decisions from the above-mentioned perspectives and to support further planning for use of previously degraded peatlands.

The information gathered within the framework of LIFE programme project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (hereinafter referred as project), has been summarized in one single model that reflects the financial, economic and environmental benefits of realizing a particular recultivation scenario.

The accuracy of model output data is determined by the correctness of the assumptions made by the model user and the data entered.

Results

Inventory of peat extraction affected areas, carried out as a part of the project, shows that there are about 18,000 ha of degraded peatlands in the territory of Latvia that has to be recultivated. By using our model and by modelling possible recultivation scenarios for the degraded peatlands in Latvia, we arrived at the conclusion that in most cases, these territories can be successfully renaturalized. As a result, renaturalization can be implemented in approximately 96% of the 18 000 ha of degraded peatlands. Blueberry cultivation is possible in 70% of degraded peatlands, while cranberry cultivation is only available in 17% of degraded peatland areas. And more than half of the degraded peatlands can be afforested.

At the same time, we found that peat extraction sites are less suitable for agricultural activities and cultivation of permanent grassland.

Recultivation of peat sites requires investments which differ for each of the scenarios considered. Blueberry and cranberry cultivation require significantly higher investment than other scenarios. Mostly this is due to the purchase of planting material, planting and installation of irrigation systems. At the same time, blueberry and cranberry cultivation promises the highest expected return.

We have concluded that the scenario with the greatest public benefit in terms of CO_2 reduction is afforestation. The two less efficient ways of degraded peat site recultivation are: establishment of permanent grasslands and creation of arable land, which does not provide CO_2 reduction. The greatest public benefit in terms of ecosystem services can be derived from afforestation, renaturalisation and paludiculture cultivation that provide significantly higher ecosystem services than other territories.

Conclusion

Evaluating recultivation scenarios from all three aspects - environment, climate and socio-economic benefits, we can conclude that although initially blueberry cultivation requires the highest financial investment, in a 10 year period, the financial return from this type of recultivation is the highest.

Assessing the recultivation scenarios from the climate change mitigation perspective, we can conclude that in a 10 year period, the highest benefit is from affforestation.

Assessing potential recultivation scenarios from an ecosystem service point of view, we have concluded that natural areas have the greatest value.

By evaluating the results described above, it can be concluded that the decisions in relation to recultivation of degraded peatlands should always be thoughtful and sustainable and based on the overall development trends of Latvia.

It is important to note that after peat extraction and transitioning the area to another type of land use, recovery of peat resources becomes impossible, therefore the statement that peat is a renewable resource is only true when the area is restored to a natural bog.

The research underlying this paper has been conducted within LIFE REstore "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE14 CCM/LV/001103) project, co-financed by the European Union LIFE programme.

RESPONSIBLE PEATLAND KEEPING* IN LATVIA. PEATLAND MANAGEMENT

Uldis Ameriks
Laflora Ltd.
uldis.ameriks@laflora.lv

*Peatland keeping is responsible management of the owner's peat lands (territories) – in terms of efficient use of resources to after-use of the bogs by using environmental impact compensating methods.

Land and people are the basis for long-term existence of the nation. Meanwhile, the government must ensure comprehensive and complex implementation and long-term planning of this link. Land policy is one of the principal factors. Land owners, who act with the land as natural capital, operate within the framework of this factor. Bogs are land areas that have not been reviewed as a complex. They have been looked upon separately as habitats, deposits of natural resources, degraded territories, where extraction of peat has been terminated, forest lands, and other.

Laflora Ltd. sets the production by making responsible and sustainable use of natural resources as its strategic objectives.

The European Commission has set the objective of changing the economy in Europe to climate-neutral economy within 30 years.

For the manufacturers this means the assessment of harmonising the generation and removals of emissions in the production process. In this event, the added value of the product includes the measure of producer's liability for such global challenges as climate change, preservation and multiplication of natural capital, social welfare and peace.

Peatland management involve:

Planning

If the bog is not situated in the protected territory, industrially extractable resources of peat have been found there, peat extraction is provided for by the spatial planning of the local government and the environmental impact of peat extraction operations has been evaluated, geological surveying shall be performed.

Research

Geological surveying shall be performed by inviting specialists that determine the structure, properties, quality of peat deposit, and other information, which allows to make conclusions of whether the extraction of peat is economically justified.

Preparation

Upon the receipt of the licence for the use of subterranean depths and development of peat extraction project, the preparation of the area of the peat extraction site for the extraction of peat (draining systems, construction of technological infrastructure) can be commenced.

Production and processing

Peat extraction and manufacturing of goods with the higher added value for the production of professional gardening, agricultural and forestry products.

After-use/Recultivation

a. Upon making the decision to use the bog for the extraction of peat, the decision on the use of land after the extraction of peat shall be made simultaneously.
b. This is a mandatory condition, that is determined by the regulatory enactments of Latvia prior to the commencement of peat extraction.
c. The manager shall plan the respective measures of land use (re-cultivation), with the consideration of their potential environmental impact, economic and other considerations.

Recultivation at the company

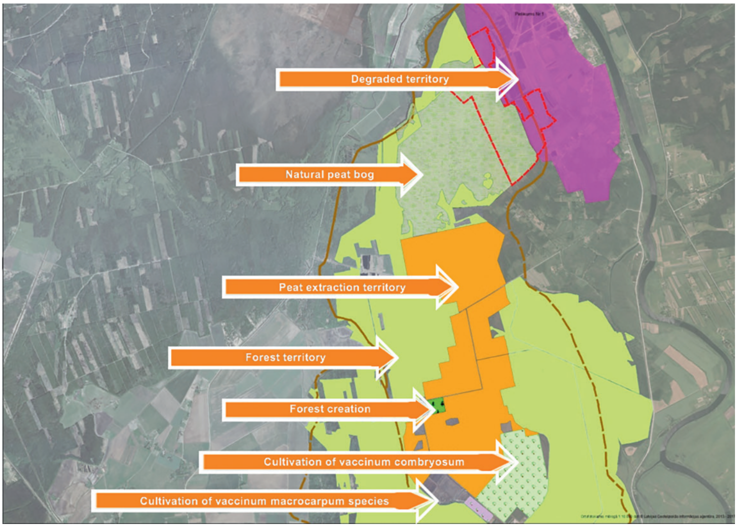
Recultivation of peat extraction site by preparing it for another type of land use is one of the most responsible decisions made by every land owner, who plans and implements the extraction of peat.

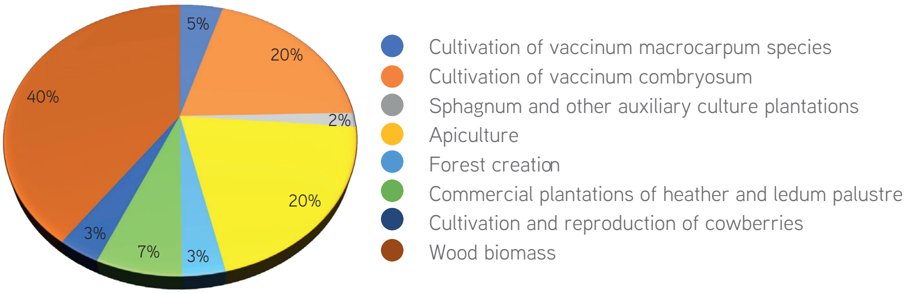
Each peat extraction site has its own specific conditions that affect the use of the land of this site after peat extraction. For instance, conditions of bog development, composition of peat, underlying base rock, opportunities of moisture regulation, etc.

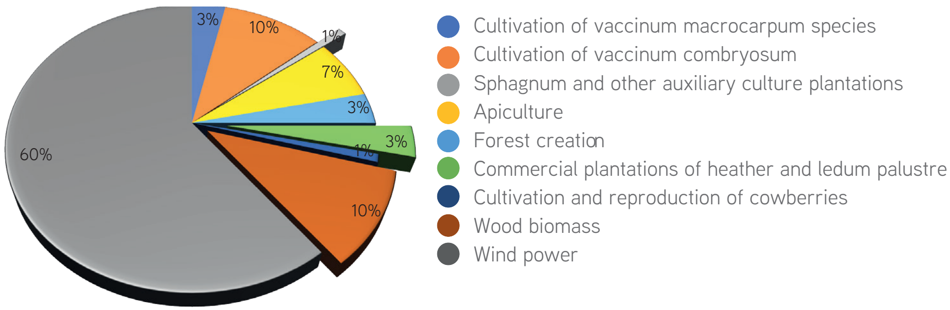
As a responsible owner of our land, we have promptly performed detailed evaluation of conditions at Kaigi peat extraction site, simultaneously identifying the targets of land use to be reached after the completion of peat extraction works.

Based on the assessment of peat extraction site, the objectives for the recultivation measures of Kaigi peat bog include the use of the site for forestry and agricultural operations, production of renewable power and gardening.

Map of Kaigu peat bog







Laflora Ltd. as the owner of peatland and bogs views the bogs as separate objects of the economy sector - Peatland cultivation. The state must view the potential of this type of land as natural capital, as well as socioeconomic factor, by formulating the sector in terms of bio-economy, circulation economy, and climate change. By implementing practical actions, Laflora Ltd. develops its vision and formulates the basic principles of its actions for the highest efficiency in using land capital for the interests of the owner, nation and state.

The peat substrate produced by Laflora Ltd. is a peat product as biomass, the absence of which makes production of healthy food from plant products unimaginable.

It is obtained from peat as raw material, by emitting climate change promoting gases from the bog. Meanwhile, plants grown in peat substrate ensure the removal of these gases.

However, the aforementioned objectives can be achieved during the manufacturing process itself, while obtaining the resource. This enables efficient use of land areas, where the resources are obtained as well as after-use is implemented, which includes cultivation of green plantations and obtaining of alternative power by developing a wind farm and biomass extraction sites.

After the extraction of resources, berry plantations and plantations of plants suitable for the respective environment, as well as forest stands will be created in the areas to ensure the removals of emissions.

Bees and bumblebees that thrive in this industrial eco-system proves the degree of its cleanliness and ensures the increase in productivity of farmed cultures.

Wind power shall compensate for the production capacities and, to some extent, for the emissions generated during the extraction process.

Modern, power saving and environmentally friendly devices and mechanisms, in synergy with the efficient and sustainable use of the land resources, are the contribution of Laflora Ltd. for the reaching of the ambitious objectives of our country and the humanity.

PEATLAND RESTORATION AT A NATIONAL SCALE: SCOTLAND'S PEATLAND ACTION PROJECT

Dr. Emily Taylor
Peatland ACTION Project, Crichton Carbon Centre
e.taylor@carboncentre.org

Keywords: peatland, restoration, greenhouse gas emissions, funding, climate change, multiple benefits, national programme.

Peatlands cover around 20% of Scotland, making them integral to the landscape and land management of the country. Estimates suggest that around 80% of Scotland's peatlands are in a degraded state and a significant source of greenhouse gas emissions. Scotland's National Peatland Plan[5], launched in 2015, has the primary aim to protect, manage and restore peatlands to maintain their natural functions, biodiversity and benefits. The Plan has the long term vision that by 2050 Scotland's peatlands will be more resilient to climate change, restoration and management is the norm, and the wider benefits to society of peatland restoration and sustainable management are fully realised through an established programme of restoration. Scotland's Draft Climate Change Plan[6] further identifies peatland restoration and management as key to reducing national greenhouse gas emissions, with an ambitious new target of 20,000ha of peatland restoration across Scotland per year. The national Peatland ACTION project is a Scottish Government funded project initiated in response to the growing understanding of the role peatlands play in climate change mitigation and the need to increase rates of restoration to deliver the multiple benefits of healthy, functioning peatlands.

5 https://www.nature.scot/sites/default/files/2017-07/A1697542%20-%20150730%20-%20peatland_plan.pdf
6 https://www2.gov.scot/Resource/0051/00513102.pdf

Peatland ACTION has the primary aim of initiating and delivering restoration projects across Scotland. Land owners can apply for grants to cover the actual costs of restoration. To facilitate projects, from design to delivery, the project employs a team of Project Officers to work with land managers to ensure best practice restoration. As a national peatland restoration project Peatland ACTION has an important role in collecting and collating new information on peatland extent and condition, setting up a national programme for monitoring restoration, and making these new national datasets available to researchers. Peatland ACTION also delivers a national training programme for contractors, ecologists and land managers so learnings from the project are disseminated and the capacity for peatland restoration increased.

Since 2012 the project has been increasing in staff and resources and to date has put over 15,000 ha of peatland on the road to recovery through restoration and informing management plans.

Peatland ACTION is an example of a successful model for delivering peatland restoration at a national scale. The project demonstrates the value of a national network of Project Officers working with land managers at every stage of restoration to deliver best practice peatland restoration. Peatland ACTION also demonstrates the added benefit of a national peatland restoration programme for consistency in data collection and reporting, of particular importance when reporting on national greenhouse gas emissions from land use and land use change.

PENNINE PEATLIFE – GEOGRAPHICALLY APPROPRIATE SPHAGNUM-BASED BOG RESTORATION TECHNIQUES

Paul Leadbitter, BA (Hons), BSc (Hons), MSc
Peatland Programme Manager, North Pennines AONB Partnership
pleadbitter@northpenninesaonb.org.uk

A significant and increasing proportion of upland blanket bog systems in northern England are no longer active, due to a range of historic and current atmospheric and direct drivers of change including atmospheric pollution, climate change, burning, drainage, over-grazing and peat extraction. The North Pennines and Yorkshire Dales contain the largest continuous blanket bog systems in England. Within this, Pennine PeatLIFE will focus on eight blanket bog habitat locations (totalling 65 810 ha) of which three are in designated Natura 2000 network sites (North Pennine Moors, Moor House Upper Teesdale, and Bowland Fells) and five are non-designated sites.

The aim of the Pennine PeatLIFE project is to demonstrate and evaluate geographically appropriate blanket bog restoration techniques suited to the harsher climatic environment of northern England and the development and showcasing of a financial payment for ecosystem services (PES) mechanism in the UK Peatland Code.

Pennine PeatLIFE will determine the most cost-effective PES restoration approach by:

1. Demonstrating financially viable region-specific and sustainable *Sphagnum* based restoration techniques for re-activating peat-forming blanket bog (*7130) in the wetter, colder and higher altitude eroded bog systems of northern England by:

a. Re-profiling and blocking eroding gullies to restore hydrology and trap sediment.

b. Stabilising and re-vegetating degraded blanket bog using locally appropriate techniques – particularly *Sphagnum* re-colonisation.

c. Demonstrating the replicability, transferability and sustainability of the different types of *Sphagnum* inoculation techniques.

d. Carrying out ecological and financial assessments of *Sphagnum* harvest and supply including trials of cutting fragments and harvesting clump.

2. Demonstrating through 'Concept to Contract' trials, the UK Peatland Code, as a viable payment for ecosystem services for upland peatlands by:

a. Developing a process for linking land managers and other stakeholders to demonstrate the UK Peatland Code administrative procedures.

b. Drawing up management plans and design documents and implementing administrative and accounting processes for each site.

3. Demonstrating new approaches using Unmanned Aerial Vehicles (UAV) to assess vegetation change as a proxy measure for monitoring the trajectory of change in ecosystem services benefits of blanket bog undergoing restoration and as a validation tool for the UK Peatland Code financial instrument by:

a. Using repeat high resolution UAV flights to assess change trajectories and validate ecosystem services benefits of restoration.

b. Assessing the viability of using UAV as a cost effective and viable monitoring tool for Peatland Code agreements.

4. Disseminating the demonstration activities to policy makers, landowners and managers, government agencies, NGOs, and other key stakeholders in the UK and across the EU by:

a. Bringing together past and present LIFE funded peatland projects from across the EU to review past work and to develop a consistent approach to peatland restoration.

b. Establishing a Pennine PeatLIFE website and social media presence.

c. Developing a programme of local, regional, national and international workshops, demonstration events and press events to disseminate lessons learnt and best practice from the project.

d. Working with NGO partner Eurosite to organise international knowledge exchanges on *Sphagnum* techniques and the UK Peatland Code.

e. Producing a series of reports and other accessible literature throughout the project culminating in a final report and recommendations for the future.

Pennine PeatLIFE is led by the North Pennines Area of Outstanding Natural Beauty (AONB) Partnership in collaboration with Yorkshire Wildlife Trust and Forest of Bowland AONB Partnership. Pennine PeatLIFE is funded by the **EU LIFE programme** with match funding from **Yorkshire Water, United Utilities, Northumbrian Water** and the **Environment Agency**.

PEATLAND RENATURALIZATION EXPERIENCE IN LATVIA AND RESULTS OF VEGETATION STUDIES IN LIFE RESTORE PROJECT

[1]Māra Pakalne, [2]Laura Grīnberga
[1]University of Latvia, Association "Baltic Coasts",
[2]Latvian Museum of Natural History
mara.pakalne@lu.lv

Introduction

Natural peatlands are ecosystems with high biodiversity, conservation, climate regulation and human welfare value. They are the most efficient terrestrial ecosystems in storing carbon while degraded peatlands after drainage and peat extraction have lost these values and are the major source of greenhouse gas emission. Degree of peatland degradation, water supply, evaporative water loss, presence of companion species has a direct impact on greenhouse gas emission.

Peatland renaturalization favours the decrease of the emission of greenhouse gases as on the bare peat of post-harvested peatlands *Sphagnum* and other mire species are reintroduced.

Aim of peatland vegetation studies was to describe the plant species assemblages which have established spontaneously on post-harvested peatlands in Latvia. In the process of spontaneous revegetation of peat fields re-establishment of a new plant cover characterising dry and wet habitats and successional stages between them was observed.

Post-harvested peatland recultivation includes renaturalization which aims in restoration of peatland ecosystem functions (water storage and peat development) and vegetation in post-harvested peatlands.

Peatland renaturalization, inventory of post-harvested peatlands, as well as raised bog habitat and hydrology restoration was carried out within the European Commission LIFE programme project LIFE REstore "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE14 CCM/LV/001103).

Material and methods

In May 2018 peatland renaturalization experiment was carried out in the post-harvested peatland part of Lielais Ķemeru tīrelis Mire in the Ķemeri National Park. It included reintroduction of *Sphagnum* species (*S. magellanicum, S. rubellum, S. fuscum, S. cuspidatum*) and other raised bog species in the area of 4,4 ha. The aim of the experiment was to determine the most effective way of peatland renaturalization by planting various combinations of *Sphagnum* species and mire plants. Prior to *Sphagnum* reintroduction, site hydrological conditions were improved, habitat and hydrological monitoring carried out.

Spontaneous vegetation re-establishment was evaluated in 32 post-harvested peatlands in Latvia where different techniques of peat extraction, like block-cutting or peat milling were applied. In the studied sites peat extraction has ceased recently or up to 70 years ago. Characteristic vegetation, type of peatland, moisture conditions, presence of drainage system and restoration possibilities were assessed. In various stages of vegetation re-establishment characteristic plant species assemblages were determined which depend on the residual peat type and depth, site microtopography, peat mining technique and time when peat harvest was ceased.

The other project site is Lauga Mire Nature Reserve where in November 2018, in total 3 peat dams were built to stabilise the water level Višezers Lake and restore the degraded raised bog habitats in the surrounding area.

Results

During the study, areas where peatland recultivation can be carried out were distinguished including Lielais Ķemeru tīrelis Mire post-harvested area. The first results of renaturalization experiment in the site show that the dry summer of 2018 had a direct influence on the regrowth of *Sphagnum* species as it was difficult to keep the water level high enough for *Sphagnum* growth. Still, in autumn the regrowth of *Sphagnum* species was observed.

Post-harvested peatland vegetation study in Latvia reveal that the key factors determining spontaneous vegetation re-establishment is water table and residual peat layer. Peatland vegetation regeneration can take place only in wet conditions which are essential for restoration of peatland functions – carbon sequestration, water regulation and peat formation.

In the studied peatlands plant species assemblage re-establishment was determined on raised bog and fen peat, dry and moist conditions, open water bodies, as well as forested and grassland habitats, from which dominated those on raised bog peat, for example, in Lielsala and Nida peatland. In dry conditions on raised bog peat with acidic soil conditions cotton-grass *Eriophorum vaginatum* and heather *Calluna vulgaris* dominate, while in wetter conditions cotton-grass can be accompanied by *Sphagnum* and other peatland species, like *Drosera rotundifolia*, *Oxycoccus palustris, Andromeda polifolia*. Optimal moisture conditions can lead to the pioneer stages of raised bog vegetation with other *Sphagnum species*, like *S. fuscum* and *S. rubellum*. In some places on fen peat transition mire vegetation with *E. polystachion,* accompanied by *Sphagnum* species develop.

Vegetation development in block-cutover peatlands is more successful than in milled peat fields. Establishment of peat-forming vegetation on milled peat fields is rare as the water level is a low. *Sphagnum* moss can grow only in areas where water level is not 0,3 m below peat surface. If peat layer is thicker, more important is the impact of groundwater level and recovery of vegetation characteristic for raised bog/transition mire is limited. Invasive species *Campylopus introflexus* occurs on cut-over peatlands and is an indicator of peatland degradation.

Composition of plant assemblages can vary considerably across the different stages of spontaneous vegetation development. In some areas hydro-serial gradient was observed which included *Phragmites* stands in shallow open water to drier places with fen and bog plant species assemblages, for example in Melnais Lake Mire Nature Reserve.

After peat extraction calcareous fen can develop, like in Dedziņpurvs Mire. Here on fen peat overlying lake gyttja calcareous fen vegetation was observed with rare and protected plant species, like *Schoenus ferrugineus, Cladium mariscus, Liparis loeselii* and *Primula farinosa.* Vegetation development leads here to the development of habitat of European importance 7230 Alkaline fens.

In Lauga Mire Nature Reserve the results show that after building of peat dams, it was possible to stabilise the water level in Višezers Lake which is connected to large drainage ditch. Still, there remains the influence of the nearby peat extraction area.

Conclusions

Peatland renaturalization is the only way to give back the nature the lost peatland areas after peat extraction, as well as to increase the biodiversity of post-harvested peatlands. If after the end of peat extraction, the drainage system continues to function, it cannot be considered as peatland renaturalization.

Post-harvested peatlands can remain dry for decades without vegetation if peat extraction effect remains. Only if the hydrological situation in the former peat fields is improved towards wet conditions, succession may lead towards peatland vegetation development and peat formation.

Post-harvested peatland vegetation inventory results show that main factors influencing vegetation recovery after drainage and peat extraction is water level and residual peat layer. Establishment of peat-forming vegetation with *Sphagnum* moss takes place in sites where water level is not 0,3 m below peat surface. If peat layer is thicker, more important is the impact of groundwater and recovery of vegetation characteristic for bog/transition mire is limited.

When vegetation has established on post-harvested peatlands, the decrease of greenhouse gas emissions can be expected.

WISE USE OF DEGRADED PEATLANDS – TOOL TO MITIGATE CLIMATE CHANGE

Nerijus Zableckis
Lithuanian Fund for Nature
nerijus.z@glis.lt

Peatlands play important role in both the mitigation of climate change and adaptation. However European peatlands are highly degraded, therefore EU counts as the second biggest polluter of global greenhouse gas (GHG) emissions from peatlands following Indonesia, contributing 17 % of global total peatland emissions (Greifswald Mire Centre, 2018). Lithuania is ranked as the 9th in the top list of key countries with emissions from drained organic soils after Latvia (5th place), and Estonia (8th place).

Peatlands cover 10,3 % (653,933 ha) of the country's territory based on recent estimations (Lithuanian Fund for Nature, 2018), out of which about 2/3 (440,000 ha) are considered as drained. According to Lithuania's National Inventory Report of 2018 organic soils emitted 1,900 kt. of CO_2 eq. However, according to the recalculation of emissions using updated IPCC emission coefficients (2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands) Lithuanian drained peatlands appeared to be responsible for fivefold higher emissions reaching 10,810 kt Co2 eq (Nature heritage Foundation, 2018). Majority of emissions originate in agriculturally utilized land, which cover 39 % (251,000 ha) followed by forestry and peat extraction. Peat extraction in Lithuania occupy only 2.1 % (14,000 ha), which are actively mined. 2.9 % of all peatlands (19,000 ha) are considered as abandoned. All together peat mining sites contribute up to 1,242 kt of CO2 eq.

In the light of new climate change commitments of Paris agreement, all sectors, including those, which do not participate in EU Emission Trading System, have to contribute with reductions of GHG emissions. Lithuanian GHG emissions reduction target is 9% for non ETS sectors, where LULUCF bears a target to reduce sector's emissions by 4 %. Therefore change of peatland usage could be "low hanging fruit". Potential of Lithuanian peatlands to reduce GHG emissions by introduction of paludiculture was assessed by Lithuanian Fund for Nature in cooperation with Michael Succow Foundation (Project Paludiculture in the Baltics – Potentials and Capacities for climate-smart, wet use of peatlands). The results of analyses, based on GIS, legal and economic analyses showed that about 41.7 % of all peatlands (262,700 ha) could be suitable for rewetting and further utilization in form of paludiculture. Majority of such sites are drained and degraded to some level, utilized in agriculture, either arable land and/or meadows. Another more complicated question stands for the type of paludiculture and economic incentives. For example, *Sphagnum* farming could be implemented in almost 5880 ha of abandoned peat extraction sites, but today there is missing well developed technology to process harvested mosses into peat substrates.

Sphagnum farming is applied in Lithuania as part of ongoing project LIFE PEAT restore LIFE15 CCM/DE/000138 "Reduction of CO_2 Emissions by Restoring Degraded Peatlands in Northern European Lowland". Mosses are reintroduced in 10 ha area of extracted part of Aukstumala peatland aiming to restore former ecosystem, which existed before peat mining. It is expensive method due to high costs spent on infrastructure, e.g. installment of fields, water supply system, research etc. Also, LIFE project will restore 4 other abandoned peatlands, covering 460 ha until spring 2020. Main restoration actions: removal of woody vegetation, installment of dams, reintroduction of *sphagnum* in most degraded parts. Additionally, LIFE project will fil the gaps in GEST (*Greenhouse gas emission types on vegetation, Couwenberg, 2011*) approach by measuring direct gases and providing emission coefficients for forested peatlands, which are the most common abandoned peatland type in Lithuania.

EXPERIENCES AND CHALLENGES OF RESTORATION AND USE OF PEATLANDS IN ESTONIA

Dr. Jüri-Ott Salm
Estonian Fund for Nature
jott@elfond.ee

Keywords: mire restoration, monitoring, paludiculture.

Framework for Climate Policy until 2050 of Estonia outlines the necessity for preservation of carbon stock both in peat soils in agricultural use as well as in peat areas used for forestry. In practice it is a big challenge to accomplish as app. 70 % of peatlands are drained and thus are presently sources for carbon leakage. On the other hand, Estonian Nature Conservation Development Plan (NCDP) until 2020 has targeted to restore 11 000 ha of mires by 2020. Due to active role of state, academic and NGO sector, and support from EU (e.g. LIFE programme) and national agencies near future perspective is almost two times as high. For setting priorities Estonian Ministry of Environment adapted Action Plan for Protected Mires (2016) where restoration areas have been prioritized.

Aim of the presentation is to provide an overview and challenges of potential after-use practices in drained peatland with high nature conservation value, in abandoned peat mining areas, and in degraded areas for potential wet land use practices as paludiculture. Overview of potential paludicultures for Estonian conditions is provided. Experience gained from restoration actions include different approaches: closure of ditches with different types of dams, forest coverage manipulation, re-introduction of *Sphagnum*, use of oil-shale ash. Monitoring of species, water level and plant cover are essential to quantify effects of implemented restoration measures and relevant methodologies are introduced, e.g. use of radio controlled quadcopters for larger spatial coverage for plant cover. Data collected with drones allows to develop methodologies to estimate impact of restoration as well as drainage for raised bogs and transitional mires. Also, data for estimation of carbon footprint of restoration work is collected and preliminary results are shared.

ABSTRACTS OF THE CONFERENCE POSTER PRESENTATIONS

LIFE RESTORE PROJECT POSTERS

FIVE DEMONSTRATION AREAS IN THE PROJECT – EVALUATION OF IMPACT ON THE GHG EMISSIONS

Dr. silv. Andis Lazdiņš, Aldis Butlers, Mg. silv. Ainārs Lupiķis, Arta Bārdule
Latvian State Forest Research Institute "Silava"
andis.lazdins@silava.lv

Key words: GHG, emissions, climate change mitigation, measures, wetlands.

To evaluate the climate change mitigation potential in the project demo areas (Eggleston, Buendia, Miwa, Ngara, & Kiyoto, 2006; Hiraishi et al., 2013), the default emission factors listed in the IPCC 2006 guidelines and Wetlands supplement to IPCC 2006 were usedduring the elaboration of the LIFE Restore project application . For forest lands, a CO_2 emission factor developed in Latvia is used (Lupiķis & Lazdins, 2017). This project confirmed that the CO_2 and N_2O emissions from soil are considerably smaller in the most of the land use categories except rewetted areas. The emission factors applied in evaluation of the GHG emission reduction potential according to IPCC guidelines and LIFE Restore results are provided in Table .

Table 1: Soil GHG emission factors according to IPCC guidelines and results of the LIFE Restore project

Land use category	GHG	Measurement unit	IPCC	LIFE REstore results
Forest	CO_2	tons CO_2-C ha^{-1}	2.60[7]	0.96[8]
	DOC[9]	tons C ha^{-1}	0.31	0.31
	CH_4	kg CH_4 ha^{-1}	2.50[10]	22.39
	CH_4 from ditches[11]	kg CH_4 ha^{-1}	217.00	217.00
	Share of ditches	-	3%	3%
	N_2O	kg N_2O-N ha^{-1}	2.8[12]	-0.05
Cranberry plantation[13]	CO_2	tons CO_2-C ha^{-1}	2.80	0.75
	DOC	tons C ha^{-1}	0.24	0.24
	CH_4	kg CH_4 ha^{-1}	6.10	5.72
	CH_4 from ditches	kg CH_4 ha^{-1}	542.00	542.00
	Share of ditches	-	5%	5%
	N_2O	kg N_2O-N ha^{-1}	4.3	0.22

7 Table 2.1 Tier 1 CO2 emission/removal factors for drained organic soils in all land-use categories.
8 LIFE REstore results
9 Table 2.2 Default DOC emission factors for drained organic soils.
10 Table 2.3 Tier 1 CH4 emission/removal factors for drained organic soils in all land-use categories.
11 Table 2.4 Default CH4 emission factors for drainage ditches.
12 Table2.5 Tier 1 direct N2O emission/removal factors for drained organic soils in all land-use categories
13 Expert assumption for the IPCC default scenario that GHG emissions from soil, except N2O, corresponds to GHG emissions from peat extraction field and N2O emissions from soil corresponds to N2O emissions from soil in grassland.

Land use category	GHG	Measurement unit	IPCC	LIFE REstore results
Blueberry plantation[14]	CO_2	tons CO_2-C ha^{-1}	5.30	1.13
	DOC	tons C ha^{-1}	0.31	0.31
	CH_4	kg CH_4 ha^{-1}	1.80	25.87
	CH_4 from ditches	kg CH_4 ha^{-1}	1165.00	1165.00
	Share of ditches	-	5%	5%
	N_2O	kg N_2O-N ha^{-1}	4.3	0.90
Rewetted areas	CO_2	tons CO_2-C ha^{-1}	-0.23[15]	1.31
	DOC	tons C ha^{-1}	0.24	0.24
	CH_4[16]	kg CH_4 ha^{-1}	122.67	122.67
	CH_4 from ditches	kg CH_4 ha^{-1}	-	-
	Share of ditches	-	-	-
	N_2O	kg N_2O-N ha^{-1}	-	0.21

Characterization of demo sites including initial and proposed land use is provided in Table 2. Expert judgments are used to calculate carbon stock changes in other pools; a 30 years period is assumed in calculation. Carbon stock changes in other pools are calculated as difference from the current situation.

Table 2: Characterization of demo sites

Demo site	Area, ha	Current land use category	Groundwater level	Nutritional regime	Proposed land use category
Kaigi bog	9.45	Peat extraction field	30-50 cm	Nutrient poor	Forest
	4.2				Blueberry plantation
Kaudzīši bog	3.4				Cranberry plantation
Ķemeri bog	0.46	Abandoned peat extraction field	0-10 cm		Rewetted area (sphagnum)
Lauga bog	309				Rewetted area

14 Expert judgement for IPCC default scenario that GHG emissions from soil corresponds to the emissions from grassland

15 Table 3.1 Default emission factors and associated uncertainty, for CO2-C from rewetted organic soils.

16 Table 3.3 Default emission factors for CH4 from rewetted organic soils.

Table 3: Carbon stock changes in other pools

Carbon pool	Measurement unit	Afforested land	Blueberry plantation	Cranberry plantation	Sphagnum field	Rewetted area
Living biomass	tons C ha^{-1}	93.15	-	-	-	-
Dead wood	tons C ha^{-1}	4.50	-	-	-	-
Ground vegetation	tons C ha^{-1}	2.00	25.00	13.60	-	-
Total	tons C ha^{-1}	99.65	25	13.6	-	-
Average stock changes	tons C yr^{-1}	1.99	0.5	0.27	-	-
	tons CO_2 yr^{-1}	7.31	1.83	1	-	-

Summary of GHG emission reduction projections in the demo sites of the LIFE Restore project is shown in Tables 4 and 5. The largest emission reduction potential can be found in afforested lands, however, blueberry and cranberry plantations can also contribute to the reduction of GHG emissions. Both scenarios, which are associated with rewetting, results in an increase of the GHG emissions; however, these emissions are considered as non-anthropogenic therefore should not be accounted.

Table 4: Carbon stock changes in other pools (tons CO_2 eq. ha-^{1} yr-^{1})

GHG	Afforested land	Blueberry plantation	Cranberry plantation	Sphagnum field	Rewetted area
CO_2	7.79	1.67	2.26	1.98	1.98
DOC	0	0	0.26	0.26	0.26
CH_4	-0.29	-0.38	0.13	-2.62	-2.62
CH_4 from ditches	0	0	0	0	0
N_2O	0.23	-0.21	0.1	-0.08	-0.08
Total	7.73	1.08	2.75	-0.46	-0.46

Table 5: Carbon stock changes in other pools (tons CO_2 eq. yr^{-1})

GHG	Afforested land	Blueberry plantation	Cranberry plantation	Sphagnum field	Rewetted area	Total
CO_2	73.64	7.02	7.68	0.91	612.25	701.5
DOC	0	0	0.87	0.12	79.31	80.3
CH_4	-2.73	-1.58	0.43	-1.21	-809.81	-814.9
CH_4 from ditches	-	-	-	-	-	-
N_2O	2.16	-0.9	0.35	-0.04	-23.71	-22.13
Total	73.07	4.54	9.34	-0.21	-141.96	-55.23

Assuming that the GHG emissions from rewetted areas should not be accounted as non-anthropogenic, the net GHG emission reduction from the demo sites equals to sum of the emissions reduction from afforested areas, blueberry and cranberry plantations (87.0 tons CO2 eq. yr-1) and GHG emissions from rewetted areas before implementation of the LIFE REstore project (2676.5 tons CO2 eq. yr-1), in total 2763.5 tons CO2 eq. yr-1.

This study is implemented within the scope of the EU LIFE programme project LIFE14 CCM/LV/001103 "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore).

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INVENTORY OF TERRITORIES AFFECTED BY PEAT EXTRACTION AND ITS RESULTS

[1]Juris Pētersons, [2] Dr. silv. Andis Lazdiņš
[1]Association "Baltic Coasts", [2]Latvian State Forest Research Institute "Silava"
info@baltijaskrasti.lv

Keywords: Peat extraction, areas affected by peat extraction, re-cultivation peatlands, degraded by peat extraction.

Introduction

Peat extraction is the main source of greenhouse gas (GHG) emissions in the wetland category. From 2026, GHG emissions should be monitored and GHG reductions in managed wetlands should be promoted. The most important activity affecting the situation in Latvia is peat extraction, both in areas where peat extraction is carried out and areas which have not been re-cultivated after the peat extraction. It was important to clarify the impact of peat extraction in Latvia within the framework of the LIFE REstore project. Therefore, an inventory of areas affected by peat extraction was carried out between 2016 and 2018.

Aim

To determine all areas affected by peat extraction in Latvia. To identify areas affected by peat extraction that are still used for peat extraction, which have been re-cultivated, and which have to be re-cultivated. To find out the situation of peat extraction in degraded peatlands so that decisions can be made about better ways of re-cultivation.

Materials and methods

In order to identify the areas affected by peat extraction in Latvia, the first step was to identify the chamber of such areas using ortho-photographic images (image series from 1994 to 1999, 2001 to 2005, 2005 to 2008, 2010 to 2011 and 2013-2015), as well as the Google Earth publicly available satellite image library (QGIS QuickMapServices). In some cases, Google Timelapse service was used, as well as topographic maps of Latvia in scale 1:10 000 (Cycle 4).

At the same time, all Latvian municipalities were invited to provide available information on peat extraction sites in their territory or at the sites of peat extraction sites affected by peat extraction. Several local governments in Latvia gave precise indications as to where peat extraction has taken place or is taking place in their territory.

Expert interviews were also carried out in the areas of inventory of territories affected by peat extraction. In the interviews with long-term representatives of peat extraction and forestry, separate areas affected by peat extraction were identified as well as names of areas, boundaries of peat extraction areas and other information useful for inventory.

The data obtained on all areas affected by peat extraction were compared with the information on peat deposits accumulated at the LEGMC State Geological Fund, as well as information available in the publication "Peat Fund" (Latvian State Land Reclamation Design Institute 1980). Detailed information on 95 affected areas was obtained from the State Geological Fund. Information on seven peat extraction sites for inventory needs was obtained from site owners and managers.

Information on 78 peat extraction areas was obtained through field work. Within the framework of these works, peat samples and photos of territories were obtained. Also, the thickness of the remaining peat layer, top peat layer (up to 0.3 m depth) type and degree of decomposition, water pH and groundwater level at the time of the survey were determined, along with a description of ditch systems present in the respective territories and the sediments under the peat were analysed.

After the chamber identification of the areas affected by peat extraction, the processes taking place in them and their area (ha) were evaluated in three categories: (1) areas where peat extraction is taking place currently; (2) Areas re-cultivated after peat extraction and type of re-cultivation (3) areas not re-cultivated after peat extraction.

Results

A database of peat-affected areas has been prepared and created in the geospatial information environment (GIS) -based data management system "Oak". The database contains all 237 areas affected by peat extraction and the boundaries of peat extraction. The total area affected by peat extraction in Latvia is 50 179 ha. Of these, 15 008 ha is where the peat extraction is currently taking place, 17 161 ha of land have been re-cultivated after peat extraction and 18 010 ha of degraded peatlands have not been re-cultivated after peat extraction.

The inventory of areas affected by peat extraction revealed that the sites were not homogeneous. For every area affected by a peat extraction operation, both water bodies, forests, and degraded, non-cultivated peatlands and other territories were identified. as well as different conditions (type of residual top layer of peat and its physico-chemical properties, degree of decomposition of peat, etc.). Various nuances and differences are not detailed in the database of areas affected by peat extraction.

The largest area affected by peat extraction in Latvia covers more than 5 100 ha (Seda bog). The largest peat extraction area where peat extraction is currently taking place is the Skrebeļi-Skrūzmaņi peat field in the Rožupe civil parish of Līvāni municipality (1 077 ha). The average peat extraction area of one peat extraction site is just over 200 ha, while the smallest active peat extraction site is just 13 ha large. The area affected by peat extraction is up to 100 ha, with nine areas affected by peat extraction covering over 1 000 ha.

Activities have been implemented with the financial support of European Commission LIFE Programme and the Administration of Latvian Environmental Protection Fund, within the framework of project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103).

LIFE RESTORE PROJECT OPEN ACCESS DATABASE AND ITS APPLICATION

M.Sc. geol. Ieva Bukovska
Nature Conservation Agency of Latvia, LIFE REstore project
ieva.bukovska@daba.gov.lv

Keywords: database, geographical information systems, peatland inventory.

Introduction

The database has been developed with a purpose of summarising and visualizing data gathered in degraded peatland inventory that was carried out in the LIFE Restore project. It is an open access GIS-based database and functions as part of the Latvian Nature Data Information System "Ozols" (Oak):

https://restore.daba.gov.lv/public/eng/database1/.

For visualization of data layers and information analysis, two applications and one *Story map* were developed. Database includes information on 237 peatlands, including 78 peatlands for which inventories were conducted through geological surveys (characteristic parameters of peatland); data on 301 peat cores; 127 vegetation data forms from peatlands; soil analysis data from GHG measurement sites, and other information. Database was developed by SIA "Envirotech", which is the leading company in the geographical information systems in Latvia.

Database and relevant tools

The database is developed as part of *Story Maps for ArcGIS Map Series* which consists of two *Web AppBuilder for ArcGIS* and one *Story Map for ArcGIS Tour* application. Each of them provides different information and geospatial data. User guide has been developed for more convenient use of database and is available on the project web page. Also a short video on how to use the database is available. The LIFE Restore database is an open access GIS-based database and functions as part of the Latvian Nature Data Information System "Ozols" (Oak):

https://restore.daba.gov.lv/public/eng/database1/.

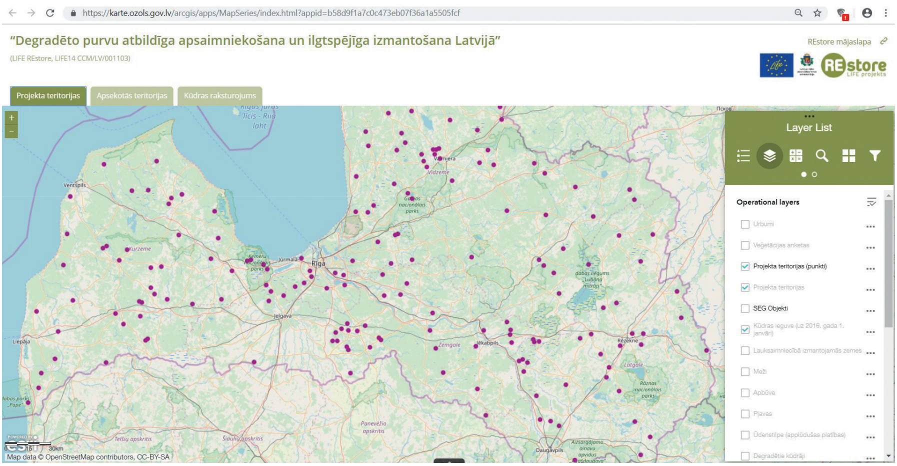
The database provides **spatial data layers** as follows:

- peatlands affected by peat extraction (~ 50 thousand hectares);
- active peat extraction areas (~ 15 thousand hectares);
- type of land use (agriculture, forests, meadows, construction, water body (flooded areas) - ~17 thousand hectares of areas where rehabilitation measures have been or are currently being implemented;
- abandoned extracted peatlands (~ 18 thousand hectares) where rehabilitation should be carried out;

- peatland boundaries from the Peat Fund (1980);
- geographical information where peat cores were collected, field survey information of 78 peatlands (~10 thousand hectares), photographs of peatlands and peat cores, thickness of the remaining peat layer, peat analysis data (peat type, decomposition degree, pH etc.).
- analytical data from GHG measurement sites and information about vegetation inventory in 32 harvested peatlands covering area of more than 32 thousand hectares. Overall 127 vegetation data forms are included in the database.

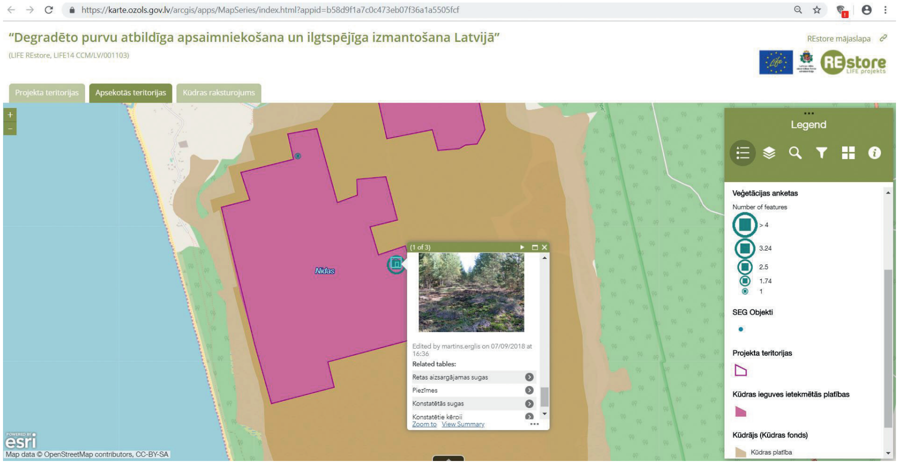
The database allows to view data in a map view, pop-up windows and in attribute tables, allowing to filter, query and analyse data. The tool bar includes the legend of the map, a list of layers, search function for territories, a base map gallery and a data filtering function for all peatlands included in protected natural areas and project demo sites.

Application “**Project territories**” provides information about all the geospatial data layers included in the database and was designed to allow end-user access to the data gathered during LIFE Restore inventory of 50 thousand hectares of peatlands in Latvia affected by peat extraction.



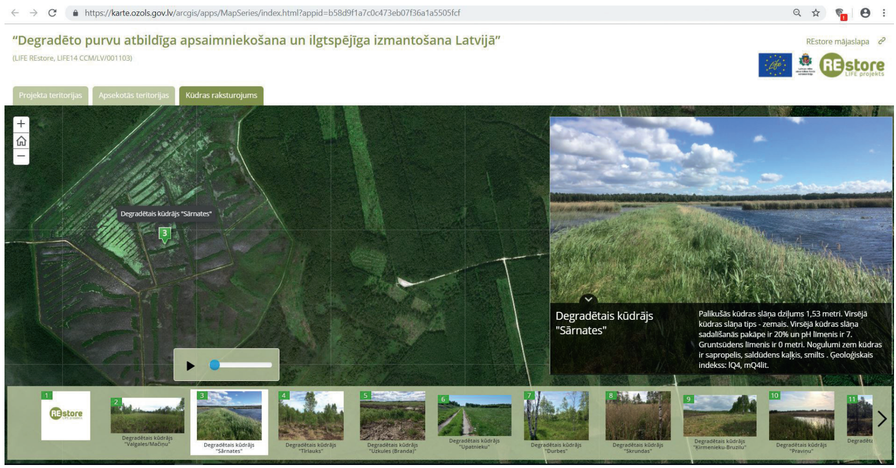
The database map view of peatlands in Latvia affected by peat extraction

Application “**Surveyed territories**” comprises similar information, but data layers are different - with an emphasis on the vegetation inventory data and geological survey core data, as well as the locations of greenhouse gas emission measurements in 41 site in Latvia and the soil analysis data. The vegetation inventory data has been processed using the *Survey123 for ArcGIS* surveying features.



The database map view of detailed information on the vegetation inventory data obtained at the Nida bog

A story map "**Peat characteristics**" is developed to gain more detailed information about 78 territories of the field survey, including main peat parameters, such as peat layer thickness, decomposition degree, pH, groundwater levels and representative photos of surveyed peatlands etc. This section presents a sequence of photos along with the field survey information of 78 peatlands, linked to an interactive map.



Story map for ArcGIS **Tour of field survey data of 78 degraded peatlands, an example of the degraded peatland "Sārnates"**

Conclusion

The database provides detailed information about the peatlands affected by the peat extraction in Latvia, including their location, area, condition and properties of residual peat, and thus it will be useful in planning sustainable management of degraded peatlands and choosing the most appropriate after-use type for particular peatlands. This database will be a useful as a tool and the source of information for state and municipal land managers, as well as private land owners and organizations interested in peatland use and conservation.

Activities have been implemented with the financial support of European Commission LIFE Programme and the Administration of Latvian Environmental Protection Fund, within the framework of project “Sustainable and responsible management and re-use of degraded peatlands in Latvia” (LIFE REstore, LIFE14 CCM/LV/001103).

THREE-DIMENSIONAL HYDROGEOLOGICAL MODELLING IN DEMONSTRATION SITES IN LAUGA AND ĶEMERI BOGS

Olģerts Aleksāns
Juris Pētersons
info@baltijaskrasti.lv

Key words: Hydrological and hydrogeological research, three-dimensional modelling, groundwater flows, digital terrain model, laser scanning (LiDAR) data.

Introduction

In the framework of project “Sustainable and responsible management and re-use of degraded peatlands in Latvia” (LIFE REstore, LIFE14 CCM/LV/001103), it was planned to rehabilitate two peatland ecosystems which were degraded by peat extraction and drainage. Rewetting and mitigation of drainage influence were necessary for raised bog in Lauga Nature Reserve. Restoration of raised bog by inoculation of *Sphagnum* moss was planned in the Ķemeri mire (Ķemeri National Park).

Hydrogeological and hydrological studies aimed at elimination of problems found in both areas and at evaluation of peatland ecosystem recovery possibilities. This paper provide a summary of the experience of LIFE REstore project in three-dimensional hydrogeological modelling of the two project areas. The results of this study were subsequently used for the planning of rewetting and after-use planning of experimental areas, as well as for elaboration of a draft re-use design (or technical design).

Aim of the task

To elaborate a three-dimensional hydrological model for estimation of the hydrological regime, determine water flow directions (horizontal and vertical) and amount for experimental territories in Lauga and Ķemeri mires.

Materials and methods

The three-dimensional models of the project sites were developed using the geospatial data set provided by the Nature Conservation Board. The digital terrain model is provided for: modelling of surface and groundwater flow; analysis of terrain slopes; gradient analysis of water courses and drainage ditches; identification of watercourse catchment basins; analysis of morphometric parameters of the mire surface. The digital terrain model is also being used for hydrogeological modelling of groundwater presence.

For the creation of the digital terrain model, laser scanning (LiDAR) data were used, allowing to obtain a three-dimensional data set of the surface where X, Y and Z coordinates are assigned to each point with a precision of 5–20 cm (Figure 2). For data processing, a licensed copy of the *Global Mapper* software was used, and its specific data processing module LiDAR.

Hydrogeological modelling was carried out in the Environmental Modelling Centre of the Faculty of Computer Science and Information Technology, Rīga Technical University. The model has been used: to determine the distribution of groundwater level, to identify groundwater flows and elements of their balance, and to assess the impact of drainage ditches on the overall status of groundwater in project areas and adjacent areas. The study was conducted using *Groundwater Vistas 6* (Environmental Simulations 2004). For the graphic design, *Surfer 12* (Golden Software 2011) software was used. Data of Latvian hydrogeological model LAMO4 developed by Environmental Modelling Centre (Spalviņš 2015) were used.

The hydrogeological model consists of eight layers. The first and eighth are serving as boundary conditions with a fixed water level. The assumed thickness of these layers in the model is only 0.02 m, and they do not describe the actual geological layers in nature. However, they are needed as virtual elements in the model to define its boundary conditions. Also, the aquiclude No 2 is only necessary for the correct ascription of drainage ditches to the terrain.

The third, fourth and fifth layers in the model represent, respectively, the upper B3, the middle B2 and the lower part B1 parts of the peatland. The thickness and hydraulic conductivity k of these parts were chosen based on the results of B. Maslow (Маслов 2008). The thickness of the upper part B3 is 0.7 m, $k = 0.1$ m/d. The thickness of parts B2 and B1 is the same, but their hydraulic conductivities are $k = 0.01$ m/d and $k = 0.001$ m/d, respectively.

The approximation step of the hydrogeological model grid plane is 4 meters. Digital terrain model adapted to the model's requirements was used as an upper boundary condition. Line of peatland edge separates peatland from sandy loam, for which, like for the Latvian hydrogeological model LAMO4, hydraulic conductivity k = 0.0014 m/d.

Quaternary moraine sediments gQ are modelled by Layer 6, the lower surface of which is taken from LAMO4; k = 0.0014m/d was assumed as a moraine sediment hydraulic conductivity (Маслов 2008). As an upper gQ surface HM, a plane 53 m above the sea level was used in the distribution range of mire sediments (peat); it ensures the changing peat deposit thickness in the model. In the south-western corner of the model, the height of this surface decreases due to terrain depression.

Aquiclude G3gj1z is modelled by Layer 7. Its thickness varies from a few meters in north-north-west part to 15m and more in the southeast corner of the model. The assumed hydraulic conductivity for Gauja aquiclude is k = 0.00028 m/d, using LAMO4 data (Spalviņš 2015).

Results and conclusions

Preparation of three-dimensional hydrological models and determination of water flow directions and amount was an important step for planning of rehabilitation and rewetting of experimental territory in the Ķemeri and Lauga mires.

The hydrological model of the Lauga mire allowed identifying the boundary of its central catchment area. According to research results it covers most part of the raised bog. Modelling results allowed to assess the importance of Višezers lake in the existence of the Lauga mire, as well as to determine the directions and velocities of water exchange. It was found that the Lauga mire is a place where groundwater resources are being supplemented. Using the obtained data, it was possible to develop innovative technical solutions for the rewetting of the Lauga mire and to present and justify this approach in negotiations with land owners of adjacent territories, as well as in Limbaži municipality Building Board, Regional Nature Conservation Board, and other institutions.

Modelling in the experimental area in the Ķemeri mire allows us to understand the complexity of this territory. It was found that in area where *Sphagnum* inoculation was planned, the modification of hydrological regime was necessary, in order to make the site suitable for *Sphagnum* moss and other raised bog plant species. Hydrological regime modification is aimed at ensuring the water level which is suitable for mire vegetation. For the preparation of area for *Sphagnum* planting, the surface levelling was necessary, in order to minimise surface gradient and to ensure free water inflow. It was also necessary to make sure that the hydrological conditions in adjacent territories at the greatest possible distance are stable and similar to those in the test area.

AFTER-USE OF POST-HARVESTED PEATLANDS AND RESTORATION OF THE RAISED BOG: ASSESSING THE ECONOMIC VALUE OF ECOSYSTEM SERVICES

Dr. paed. Aija Persevica, Dr. oec. Elina Konstantinova, Dr. oec. Liga Brunina
Association "Baltic Coasts"
aija.persevica@baltijaskrasti.lv, elina.konstantinova@baltijaskrasti.lv, liga.brunina@baltijaskrasti

Keywords – ecosystem services, ecosystems, economic valuation, decision making

Introduction

Ecosystem services are understood as all benefits that the humanity gains from ecosystems. By using the ecosystem services approach, it is possible to demonstrate the benefits of any given ecosystem and, at the same time, model the development scenarios of the territory by comparing both the potential benefits and the expected risks, and take informed decisions.

On one hand, natural mire can ensure biodiversity and regulate the climate, water and nutrient cycles. On the other hand, the peat accumulated in bogs is an important resource that can be used both in energy, agriculture, production of thermal insulation materials, as well as for other purposes. By evaluating ecosystem services, we can arrive at a more complete picture of the benefits provided by an ecosystem, to compare them, and make sustainable decisions about future use and management of the territory.

In the framework of project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103) (hereinafter "project"), ecosystem services were assessed in five demo sites. Four of them are located in post-harvested peatlands, where after-use measures included: tree planting (afforestation); plantations of high blueberries and large cranberries; restoration by planting (inoculation) of *Sphagnum* moss. The fifth site is located in a degraded raised bog, and rewetting was the after-use measure here.

The Aim of the Research

The aim of this research is to present and discuss the ecosystem services assessment and economic valuation for sustainable management of degraded peatlands in Latvia.

Methods

Ecosystem services, in general, are divided into three major categories:

- Provisioning services – direct gain of materials and resources from ecosystems (food, drinking water etc.);
- Regulating services – the services that ecosystems provide by acting as regulators e.g. regulating the quality of air and soil or by providing flood and disease control;

- Cultural services – non-material benefits from ecosystem services, which influences the psychological and mental state of the persons (active/passive recreation, environmental education etc.);

For mapping and evaluation of ecosystem services a Matrix-method of Ecosystem Services was used, developed by German scientist B. Burkhard.

In this project, the assessment of ecosystem services included the following activities:

1. Determination of land cover types and their areas in project demo sites;
2. Determination of ecosystem services and their indicators in demo sites;
3. Assessment of ecosystem services by evaluating each indicator of each land cover type.

Economic evaluation of ecosystems and their services are necessary in order to assess the anthropogenic impact on ecosystems, by using the values ecosystems and the services they provide:

- Economic evaluation methods of ecosystem services allow to demonstrate the indirect value of the ecosystem services, something that is difficult to assess for the general public, but which has a demonstratable monetary value;
- Economic evaluation of ecosystem services helps with the decision-making when a comparison of two or more development scenarios is needed. By expressing the values in uniform monetary units, the scenarios can be compared.

To assess the monetary value of ecosystem services, different methods were used: Direct pricing/Market price method; Avoided cost method, Replacement cost method; Benefit transfer method.

The economic valuation was based on data obtained from biophysical ecosystem services assessment for 28 indicators for 3 scenarios from 5, 25 and 50 years perspective.

Results

Analysing the current situation of demo sites from the perspective of their ability to provide ecosystem services, it can be concluded that existing peat extraction fields provide high economic value in the form of provision services, while on the other hand they provide very low regulation and cultural services. Natural bog territories provide high regulation services and comparatively higher cultural services. The economic value of degraded peatlands is low in all groups of ecosystem services. This conclusion demonstrates the necessity for sustainable management measures for increasing the provision of ecosystem services of degraded peatlands.

The economic assessment of ecosystem services allows to compare different land use management scenarios from different perspectives – their ability to provide supply of products and materials, ability to regulate viability of ecosystems and climate, as well as the ability to provide cultural services.

Analyzing post-harvested peatlands which were used as project demo sites for the implementation of after-use scenarios from the perspective aspect of ecosystem services, it can be seen that all values for all territories were very low.

During the five, 25 and 50 years, the most valuable ecosystem services will be provided by tree plantations providing high regulation services. Also, afforestation is seen as the most effective after-use type for global climate change mitigation.

Conclusion

Economical assessment of ecosystem services is an important support tool for decision making on different land use scenarios.

Peatland ecosystems are globally valuable in terms of biodiversity. However, the economic importance of these areas varies with respect to the potential options of economic activities to be carried out there. The sustainable management of degraded peatlands has a particular potential to make an important contribution to climate change mitigation and both economic and environmental benefits to society.

The research underlying this paper has been conducted within „LIFE REstore – "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE14 CCM/LV/001103) project, co-financed by the European Union.

ESTABLISHMENT OF HIGHBUSH BLUEBERRY *VACCINIUM CORYMBOSUM* AND LARGE CRANBERRY *VACCINIUM MACROCARPON* PLANTATIONS IN PEATLANDS DEGRADED BY PEAT EXTRACTION

Juris Pētersons
Association "Baltic Coasts"
info@baltijaskrasti.lv

Keywords: highbush blueberry, large cranberry, degraded peatland, recultivation of degraded peatlands.

Introduction

The cultivation of highbush blueberries *Vaccinium corymbosum* and large cranberries *Vaccinium macrocarpon* are among the most promising after-use types in peatlands damaged by peat extraction. It is also the most economically advantageous after-use solution if compared to other after-use types used in Latvia.

Both highbush blueberries and large cranberries grow well in peat, as there are suitable moisture, acidity and other conditions. The cultivation of these berries are economically justified, as the climate conditions of Latvia are favourable. In Europe the production of these berries is low, largely due to unsuitable climatic conditions. However, the market and the demand are high.

Aim

To verify in practice the suitability and possibilities of berry planting as a form of after-use of peatlands damaged by peat extraction in Latvia.

Materials and Methods

Highbush blueberry plantations were established in Līvbērze rural territory, Jelgava municipality, in the eastern side of the Kaigu mire, in a property of Arosa R, Ltd. The company manages 117 hectares of extracted peatlands. Highbush blueberries were planted in an area of 4.2 ha. Large cranberry plantations were established in Kaudzīši mire in the Ranka rural territory, Gulbene municipality. This is a territory where peat extraction was wrapped up only recently and is still ongoing in some other parts of the same property. Plantations were established in the area of 3.4 ha.

For berry planting extensive ground preparation work was carried out. Land surface was levelled up to the level of adjacent fields, to include it in the joint structure of fields. Removed excess material was transported away, and a smooth, even area was created. After the surface levelling, fields were milled and mineral fertilizer was applied.

When the field for blueberry planting was prepared and furrows were created with a bed shaper, with an elevation of 0.5 m and width of 0.7 m. The distance between the furrows was 3 meters. After creating of furrows, berry plants were planted manually in the elevations. For every plant, a hole was made, a plant was placed, and the hole was backfilled. The distance between the berry plants was 1–1.2 meters. Plants were watered immediately after the planting. Precipitation water accumulated in pits at the edges of fields was used for watering. Highbush blueberries were planted in June, 2017.

When the field for large cranberry was prepared, berry vines, approximately 10 cm tall, were evenly distributed throughout the field. Then, entire field was processed with soil cultivator at a depth of 3 cm. After planting, the field was first watered. Large cranberries were planted in the spring of 2018.

Results and Conclusions

Highbush blueberries can be harvested in the third or fourth year after planting. However, none of the planted plants have withered away; seedlings grow larger and have new leaves every year. Thus, it can be concluded that the planting of highbush blueberries for the after-use of extracted peatlands was successful.

Large cranberries can be harvested in the fourth year after planting, therefore it is not possible to make full conclusions about the quality of after-use work immediately after the planting. However, already three months after the planting, seedlings produced new leaves, indicative of the development of new roots and successful establishment. Similarly to highbush blueberries, it is important for large cranberries to ensure sufficient moisture in the first growing season, in order to promote the development of new roots.

Growing berries is the most profitable after-use type of extracted peatlands, as found by LIFE REstore project during the developing of peatland after-use models. If plantations are properly managed, seedlings are well cared for and berries are harvested, the investments may pay off in 8 to 13 years. Of the eight analysed types of degraded peatland after-use, also the growing of trees is financially profitable, though the payback period of this investment is longer.

Activities have been implemented with the financial support of European Commission LIFE Programme and the Administration of Latvian Environmental Protection Fund, within the framework of project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103).

PEATLAND RECULTIVATION - A CASE STUDY OF A COMERCIAL TREE PLANTATION IN A FORMER PEAT EXTRACTION AREA

Dagnija Lazdiņa, Santa Neimane, Santa Celma, Vita Krēsliņa, Kārlis Dūmiņš, Toms Arturs Štāls, Modris Okmanis, Gints Spalva, Andis Lazdiņš, Kristaps Makovskis
Latvian State Forest Research Institute "Silava"
dagnija.lazdina@silava.lv

Key words: Cutaway peatland, recultivation, *Picea abies, Pinus sylvestris, Alnus glutinosa, Betula pendula, Populus spp.*, natural vegetation.

Introduction

In countries where peat extraction is of economic importance, planting or sowing of trees as an after-use of former extraction areas is considered an economically viable and environmentally friendly solution. It is more reasonable if the area was covered by forest before the peat bog formed since during extraction the layer containing ancient tree remains is reached. If the peat extraction is continued while the drainage system is operating, the mire cannot be restored because of the low water level (Woziwoda, Kopeć 2014). The peat layer remaining after the extraction is often having unbalanced nutrient element composition and wood ash can be used for soil improvement, liming and nutrient input (Mandre et al. 2010; Kikamägi et al. 2013; Ots et al. 2017). Vegetation development after the soil improvement is very important for nutrient circulation and carbon storage in extracted peatlands (Huotari et al. 2009, 2011). Scots pine (*Pinus sylvestris*), silver birch (*Betula pendula*) and black alder (*Alnus glutinosa*) are common on forest sites with organic soils with fluctuating water levels and such conditions are also characteristic for extracted peatlands (Hytönen, Saarsalmi 2009; González et al. 2013; Lazdina et al. 2017). Female poplar clone *Vesten* is a breed developed in Belgium in a search for fast growing trees suitable for afforestation of peaty substrates.

The Aim and Scope

Testing of the tree cultivation as an after-use type for cutaway peatlands, and identification of the most effective, optimal dose of biological fertilizer – wood ash – for various tree species was the aim of designing this experimental demo site.

Materials and Methods

Recultivation of the cut-away peatland was performed in the spring of 2017 on a 9 hectare area (56°43'42.1"N, 23°34'33.3"E). Before the planting of the collection of trees the adjacent ditches were cleaned. After removal of the vegetation from the sides of the ditches, which mainly consisted of trees and reeds, wood ash was spread. For the liming and fertilization the chosen doses of wood ash were similar to the ones recommended in Finland and Sweden – 5–10 t ha^{-1}, as well as 15 t ha^{-1} – dose, which would allow the long-term observation of the correlation between the application of various soil improvement materials and the vegetation development as well as the tree growth. After the site preparation, the trees were planted in May 2017. The distance between the tree rows was 3.5 m, between the trees - 2.5 m; a 2.5 m wide strip was left along the ditches. Each variation was replicated three times. For planting of pines, birches and alders, container seedlings were used as they can be easily planted using both a shovel or a planting tube. Compared to other available types of planting material, container seedlings are less exposed to the risk of drying out because of their compact root system, which develops in enriched peat (LVM, Sēklas un stādi). The poplars were planted with 1.8 m long cuttings that were inserted into the soil at a depth of at least 50 cm (Zeps et al. 2011).

Results

The area affected by peat extraction was afforested without interrupting the peat extraction in adjacent areas. By applying wood ash to the soil the agro-chemical properties in experimental extracted peatlands were improved. In the second year after fertilization the soil acidity was reduced from $pHCaCl_2$ 3.5 to 4.2 with 5 t ha^{-1} of wood ash, up to 4.8 with 10 t ha^{-1} and up to 5.9 when 15 t ha^{-1} was spread. Soil was enriched with calcium, magnesium, phosphorus and potassium (Table1).

Table 1. Difference in soil acidity and P,K, Mg and Ca content in the soil two years after the fertilization with wood ash fertilization

Wood ash applied	$pHCaCl_2$	Total N., g kg^{-1}	P, g kg^{-1}	K, g kg^{-1}	Mg, g kg^{-1}	Ca, gkg^{-1}
Control	3,5	16,2	0,2	0,1	1	11,1
+/- in % relative to control:						
5 tha^{-1}	20	-17	50	200	50	22
10 tha^{-1}	37	-15	150	600	110	68
15 tha^{-1}	69	-25	300	1600	180	124

Vegetation development after spreading of wood ash in the topsoil changed rapidly - ground vegetation was formed – herbaceous plants took root. A total of 33–39 taxons depending on the dose of fertilizer were recognized and counted. In addition to herbaceous plants, a natural afforestation process began. Naturally occured the following trees - *Betula pubescens*, *B.pendula*, *Populus tremula*, various *Salix spp*. species, including *S.caprea.*. In areas where no additional nutrients with wood ash were applied, the vegetation was solitary or in groups, fewer species were counted.

Trees in the fertilized plantings were more vital as in control replicates. At the end of the second growing season they had grown significantly higher than in the unfertilized control plots (Figure 1).

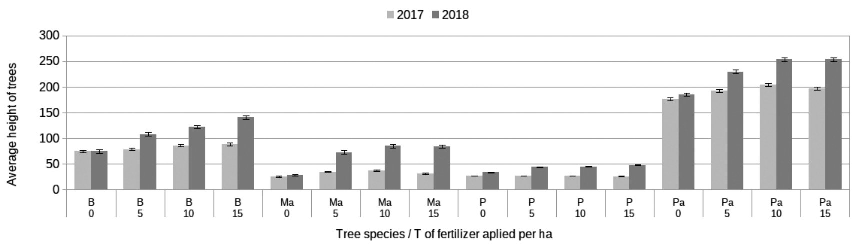


Figure 1. Average height (with standard error) of tree seedlings (Pa – poplar, B – silver birch, Ma – black alder, P – Scots pine) after the first and second growing season in fields with various doses of wood ash fertilization (0 t ha-1, 5 t ha-1, 10 t ha-1 and 15 t ha-1).

Since the cutaway peat layer in demo area is thicker than 30 cm and the water level is adjusted using ditches, according to the forest site type classification in Latvia such plantation corresponds to the type *kūdrenis* – forests on drained peat soils. Depending on the composition of planted and naturally occurring tree species, it is expected that in the future these woodlands will correspond to forest site types šaurlapju *kūdrenis* (*Myrtillosa turf. mel.*) or *platlapju kūdrenis* (*Oxalidosa turf. mel.*) with their characteristic vegetation (Zālītis, 2006).

In fields where the soil was not improved, the planted trees were less vigorous during the second vegetation season. Leaf and needle color indicated a lack of macronutrients, so that additional nutrient inputs – fertilization – is necessary there in order to keep the trees in the plantation.

If the field ditches and collection ditches in the plantation areas are not be maintained in the future, the development of conditions characteristic for *purvaiņi* (forests on wet peaty soils), *purvājs* (*Sphagnosa*) or *niedrājs* (*Caricoso-phragmitosa*) is expected and the corresponding forest types will probably develop.

Conclusions

Significant differences in tree height and vitality were observed after the second growing season. To keep the unfertilized trees alive, fertilization is needed.

After the use of wood ash the peat layer is enriched with P, K, Ca, Mg and pH levels increased depending on the wood ash dosage used.

A variety of vegetation is recorded in the first and second year after wood ash is applied.

The plantation will provide further economic benefits, promote soil shading and the following long-term carbon sequestration in tree biomass.

Activities have been implemented with the financial support of European Commission LIFE Programme and the Administration of Latvian Environmental Protection Fund, within the framework of project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103).

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RENATURALIZATION (SPHAGNUM PLANTING) OF DEGRADED PEATLAND IN LIFE RESTORE DEMO SITE AT ĶEMERI NATIONAL PARK

Agnese Rudusāne, Māra Pakalne, Juris Pētersons
Nature Conservation Agency of Latvia, LIFE Restore project
agnese.rudusane@daba.gov.lv

Introduction

Mire restoration in degraded peatlands can be ensured in several ways. The most commonly used is the water level elevation by blocking the drainage system. If wetland conditions are successfully restored, extracted peatlands will overgrow with moisture-loving plant species which later will decay and form the peat while also capturing the CO_2. Successful peatland restoration is not possible without ensuring a sufficiently high groundwater level (for example, if the peat extraction is continued in a nearby territory and therefore the drainage system is maintained). It should be taken into account that the restoration of the characteristic mire vegetation to the degree which is similar to the natural mire takes tens and even hundreds of years. Planting or re-introduction of mire plants is a new and a little tested solution in Latvia. It aims at accelerating the restoration of the characteristic mire vegetation in areas affected by peat extraction, which may speed up the restoration of a functioning wetland ecosystem.

In order to facilitate regeneration of the mire vegetation, in May 2018 experimental planting or reintroduction of sphagnum and other mire plants was carried out on a partially extracted peat field in the demo site of the project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/ LV/001103).

The Aim

The aim of the experiment was to ascertain whether the reintroduction of the characteristic vegetation after peat extraction is possible, as well as to identify the most effective reintroduction method by planting various combinations of sphagnum and other mire plant species both on pre-prepared peat surface and without the surface preparation.

Materials and Methods

The LIFE REstore project renaturalization demo site is located on the north-eastern edge of Kemeri Mire. Renovation by planting sphagnum and other high mire plants had been carried out at the peat extraction site, but the vegetation of the mire has not been fully restored for more than 30 years (since the beginning of the 1980s, when the peat extraction stopped).

Preparation works took almost two years and comprised scientific investigation, planning and coordination of tasks. The demo site was repeatedly surveyed, evaluated; participants of the experiment were consulted. The planning work started with the evaluation of the site conditions and the suitability for the chosen purpose - renaturalization. The study included a stratigraphic study of the peat that provided relevant information on the suitability of conditions for the high mire species, as well as a hydrogeological modelling, which in turn was important for assessing the possibilities of raising water levels to achieve the mire conditions. The results of the research were used in drafting the re-cultivation plan.

After the site selection and the development of re-cultivation plan, the conditions suitable for the mire vegetation restoration had to be created. At first, the excessive vegetation was removed. Then, a field ditch was blocked at the northern edge of the site, to pump out the water and to enable surface levelling. The surface was levelled (up to 8.60 m a.s.l.) towards the northern and the southern edges and trapezoidal berms were created. To prevent long-term waterlogging, two culverts (gradient 5%) were installed on the southern edge of the field ditch. The culverts were 3.0 m long and 0.15 m in diameter. They were placed next to each other with a 0.15 m gap, and covered with peat (0.5 m).

After the site preparation, the demo site was divided into four 30 x 35 m experimental plots where *Sphagnum* moss was planted. In 3 of the 4 plots the surface peat was removed and the surface was smoothened. The *Sphagnum* planting material was harvested manually in the adjacent Drabiņu Mire (a relatively undisturbed raised bog) on May 17, 2018. Vegetation was collected as clumps. The collected vegetation consisted mainly of *Sphagnum* but it also contained living fragments of other mire plants. The collected material was packed in bags and transported to the planting site. On May 18, 2018, the next day after the *Sphagnum* harvest, the mosses were planted with the help of 62 volunteers. In total, 2200 kg of *Sphagnum* were planted in an area of 3200 $m^{2.}$ The decision was taken to plant the *Sphagnum* in clusters instead of scattering its fragments. Prior to the planting, *the Sphagnum* were sorted by the dominant species and divided into small clusters (5 x 5 cm). These *Sphagnum* groups were evenly planted at about 0.5 m from one another. In some places, other mire plants were also spread, to see if they will start to grow.

After planting the fields were covered with straw in order to protect the plants from direct Sun exposure and drying out. Approximately 1500 kg of straw were spread evenly across the area. The summer of 2018 was very dry. Therefore, *the Sphagnum* plantings were watered during the first vegetation season. Water was taken from the raised bog, degraded by the peat extraction, i.e. pumped from the ditch which is located east from the demo site; a 150 m long fire hose was used. During every watering event the area was watered for 1.5 hours. Regular monitoring of *the Sphagnum* vitality and the site moisture conditions was carried out throughout the summer. The frequency of watering was determined by the weather conditions and other circumstances.

In autumn of 2018, after a very dry summer, *the Sphagnum* planting experiment was supplemented with a small terrace-shaped planting plot. Two 2 x 2 m experimental plots were set up at various depths (0.30 m and 0.15 m), after removing the top layer of the peat so that the surface to be planted was close to the groundwater table. Here also the previously used method was applied: *Sphagnum* mosses were collected from the adjacent undisturbed part of Ķemeri Mire. *Sphagnum magellanicum* was the dominant species in the collected material, but other raised bog plant species were also present. *Sphagnum* mosses were planted by hand and covered with straw. This small-scale experiment will allow drawing more in-depth conclusions about *Sphagnum* reintroduction success depending on the groundwater level.

The groundwater table was monitored to ensure regular information on the hydrological condition of the demo site and its changes during the experiment. Eight groundwater observation wells were erected in the demo site and in its immediate vicinity. Hydrological measurements were taken manually with the Electric Contact Meter *Seba KLL Mini, 10m*. The equipment consists of a smooth measuring tape with a sensing device at the end. By placing the measuring tape in a tube and slowly lowering it, the sensor contacts the water, gives out a sound signal and the result can be read out.

In 2017, 13 permanent vegetation sample plots were established in the buffer zone of the demo site, before the *Sphagnum* planting. This will provide a possibility to compare the vegetation development in the *Sphagnum* planting plots with the areas where the peat surface was not removed and *Sphagnum* mosses were not planted.

Results and conclusions

In autumn of 2018, it was observed that all species of *Sphagnum* (*Sphagnum magellanicum, S. fuscum, S. rubellum, S. cuspidatum*) have endured under the cover of straw, although in much smaller areas than they were planted. Most of the planted *Sphagnum* mosses had perished, and only small groups survived. However, less than one year is not sufficient for an objective evaluation of the experiment results.

Observations from the first year show that groundwater table in the demo site was not sufficient for the survival of the planted *Sphagnum* mosses. After the *Sphagnum* planting, groundwater table was very low – 48–57 cm below the peat surface (lowest observed was 114 cm. The amount of precipitation did not increase significantly by the end of the year. However, the groundwater table gradually increased in autumn and winter likely due to reduced evaporation. No direct correlation with rainfall has been observed. The series of observations reflects a relatively short period of time, therefore a linear relationship was not really expected.

The experiment carried out in Ķemeri Mire is vital for the evaluation of the reintroduction possibilities of *Sphagnum* mosses and other mire plants in Latvian conditions. The renaturalisation of the peat extraction sites requires the work that can only be assessed in a long term. This is an experiment whose success or failure will be measurable after several years, so a regular vegetation and groundwater table monitoring must continue.

Activities have been implemented with the financial support of European Commission LIFE Programme and the Administration of Latvian Environmental Protection Fund, within the framework of project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103).

STABILIZATION OF THE HYDROLOGICAL REGIME OF THE VIŠEZERS LAKE AT LIFE RESTORE DEMO SITE IN LAUGA MIRE

Agnese Rudusāne, Juris Pētersons
Nature Conservation Agency of Latvia, LIFE Restore
agnese.rudusane@daba.gov.lv

Introduction

Since the drainage system was installed and the peat extraction started in the 1960's, the water level in the Višezers lake has fallen by 1.3 m. This factor has affected the pristine structure of the lake. The conditions created by the land amelioration have caused significant disturbance in the natural ecosystem of the Višezers Lake and the entire Lauga Mire. Over several years, five different types of peat and wood dams have been established outside the restricted area, at the frontier of the nature reserve, increasing the water level of the Višezers Lake. Historical changes in the hydrological regime of the mire are the main factor influencing the nature in Lauga Mire, affecting both the water level of the Višezers Lake and the habitats of Lauga Mire, as well as the long term stability of the old dams.

In the framework of the project “Sustainable and Responsible Management and Re-use of Degraded Peatlands in Latvia” (LIFE REstore, LIFE14 CCM/LV/001103) renaturalization of the territory was planned by stabilizing the hydrological regime and peatland ecosystems which were degraded by the peat extraction and drainage. Rewetting and mitigation of drainage influence were necessary for the raised mire in the Lauga Mire Nature Reserve.

The Aim

Renaturalization of the territory- restoration of the hydrological regime of Lauga Mire and a long-term stabilization of the hydrological regime of the Višezers Lake in order to allow the restoration of the natural mire ecosystem.

Materials and Methods

Recultivation of the degraded peatland - renaturalization- stabilization of the water level in the long term was carried out in the demo site of the LIFE REstore project in Lauga Mire, Krimulda and Limbaži Counties. The demo site is located in the nature reserve “Lauga Mire”, which is included in the Natura 2000 network. Lauga Mire is located in the north-western part of Vidzeme, Vidriži Parish of Limbaži County and in Lēdurga Parish of Krimulda County. Total area of the mire is 1876 ha. The nature reserve includes the central part of Lauga Mire with an area of 740 ha. The nature reserve area is not populated.

To meet this aim, a 3D hydrological model was developed, the GHG measurements were made, biophysical and economic evaluation of the ecosystem services was prepared, as well as a groundwater monitoring system was installed. In order to carry out the hydrological regime stabilization works in Lauga Mire, which is an area of NATURA 2000, the activities had to be reflected in the nature protection plan. The nature protection plan was drafted, including objectives and measures aiming at the restoration of the hydrological regime of the mire and stabilization of the hydrological regime of the Višezers. The nature protection plan for "Lauga Mire" was the first nature protection plan in Latvia, which included the assessment of the ecosystem services. The Nature protection plan stated that a significant contribution to achieving the long-term objectives can be achieved by performing a single management measure - replacing the existing temporary dams with new regulated ones.

Dams were built according to the technical specification of the building design. Lauga is a raised mire that borders with peat extraction fields where peat cutting takes place, as well as cranberry plantations and the Lauga Mire Nature Reserve territory. These land uses require different water levels, so regulated dams were built and they can be manually adjusted as needed to provide the required water level.

In November 2018, the planned regulated peat dams were built. Dams were built according to a nature protection plan that justifies the need for such dams, as well as according to the hydrological research, which determined the hydrological level necessary for the restoration of the natural mire habitat. Peat dams also provide water drainage from the Višezers if the water level in the lake exceeds the maximum set in the nature protection plan, i.e. 58.3-58.5 m a.s.l.

The trees and shrubs in the area were cut to prepare for the dam construction. Ditches and other material that have accumulated over many years have been cleaned from the ditch base. Since peat dams are built on a peat layer of ~ 6.0 m the ditches were cleaned, reaching a stable peat compaction. The material needed for the construction of peat dams was taken downstream of the dam site. During the construction work it was important to get the dams in places with the existing peat layer intertwined. This ensures that the dams are firmly held in place, keeping the water pressure in the Višezers, and preventing the water flow through the edges of the dams. After construction of the dams, they were covered with a mire acrylic removed during the construction. It helps dams faster overgrow with vegetation thus faster integrating into the landscape.

Results and Conclusions

Since the dams are built of peat, after the completion of the construction work the stacked peat continues to compact and peat dams sink slightly. In order to prevent flooding of adjacent areas after the dam construction while keeping the water level in the Višezers at the level of the nature protection plan, the dams have been equipped with smooth drainage pipelines DN200. As the dam continues to sink, so will the built-in pipelines. Once the peat is fully compacted, the pipelines will no longer be at their height. The pipeline ends are therefore bent to 67°, which can be adjusted to the level of 0.01 m specified in the nature protection plan.

Seven hydrological monitoring wells have been installed in the natural mire part of the nature reserve "Lauga Mire" for evaluation of the hydrological stabilization works. Each well is equipped with a DN50 tube with a filter for monitoring water level changes. Monitoring of water level changes is carried out by the Nature Conservation *Agency – a* habitat expert performs water level measurements once a month in the installed monitoring wells. A further 10 years after the end of the LIFE Restore project, changes in the hydrological regime will be examined by the Nature Conservation Agency.

In 2019, it is too early to assess the impact of the regulated peat dams on the restoration of the mire in the Lauga nature reserve. This is a successful long-term investment in improving the state of the mire ecosystem. It is expected that dams will ensure conditions for the restoration of the protected habitat of the EU importance Distrofi Lakes (10.01 ha) and the stabilization of the Višezers current water level at 58.3-58.5 m a.s.l. Dams that were built within the LIFE REstore project will provide the conditions for further improvement of the quality of the mire habitats in the area of 309 ha (the Višezers catchment area).

Activities have been implemented with the financial support of European Commission LIFE Programme and the Administration of Latvian Environmental Protection Fund, within the framework of project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103).

A TYPE OF PEATLAND RECULTIVATION: REFORESTING

Dagnija Lazdiņa, Ingrīda Krīgere, Inārs Dreimanis, Laimdota Kalniņa, Andis Lazdiņš
Latvian Peat Association
peat@peat.lv

Keywords: peatland, reforesting, greenhouse gas emissions.

This type of recultivation involves the transformation and adaptation of former peat extraction sites or areas to be restored into forest lands to be used in forestry.

The aim of the further land use — forestry.

Conditions under which this scenario is possible:

- The type of peat forming the surface of the area to be restored: is not a restrictive criterion;
- Thickness of the remaining peat layer: is not a limiting criterion;
- pH values of the top peat to be used: > 4 (otherwise liming must be done);
- Average groundwater level: not higher than 0.35m;
- Average number of days in a year when the area is flooded: permissible for 1-2 days per year;
- Degree of decomposition of peat: is not a restrictive criterion.

When planning to grow a forest at a peat extraction site to be recultivated, the sediment composition, including chemical and filtration properties, forming the bog depression surface should be considered. A combination of these properties influences the growth conditions of the trees, the proportion of minerals in the soil, which in turn determines the choice of tree species in the respective area.

Areas where the functionality of a good drainage system has been created, which ensures an optimal moisture regime for tree growth and the necessary nutrients available for trees, can be considered as suitable for reforesting.

The moisture regime required for growing conditions of the selected tree species can be foreseen in advance and the proportion of ditches left in operation after the end of peat extraction also can be planned. At previously used peat extraction sites, the elements of the drainage system can be renewed and reconstructed by improving the soil and normalizing the environmental reaction, which can create the growing conditions necessary for tree growth.

Soil improvement at developed peat extraction sites can be done with wood ash, mineral fertilizers or sewage sludge, as well as separately liming, if the selected fertilizer does not have soil acidity-reducing properties and/or the peat layer of the field to be restored, where the plantation is planned, has increased acidity (pH $<$ 3.0). Soil improvement promotes not only the growth of trees, but also weeds, so one has to consider that soon after additional plant nutrients have been introduced, an agrotechnical treatment will have to take place, cutting the grass and herbaceous plants, if they hinder the development of new trees. Agrotechnical treatment should be provided for several years in the planted areas.

The use of wood ash in the peat extraction fields developed for soil improvement can effectively improve tree growth, and the fertilizer effect can last up to 50 years (Huotari et al., 2011)It has to be taken into account that peat has a low phosphorus absorption capacity.

If the reforesting of a historically used peat extraction site is planned which has a significant thickness of the remaining peat layer ($>$ 2 m), additional logging burdens associated with the soil's low load capacity during logging work will arise. Wood cutting in such areas should be planned during the winter period when the soil is frozen. At such sites, it is necessary to initially consider the possibility of extracting the remaining peat to an optimal thickness of the peat layer, which makes it possible to perform technical activities for mixing the peat layer with the mineral soil.

Reforesting the area of developed peat extraction sites to forest land by transforming the scenario can be done in 2 ways – forest or plantation forest. An alternative is to establish long-term tree plantations, the land is transformed into agricultural land, or its status remains unchanged. This can be applied to the purpose of planting trees, the wishes of the owner and the available financial means.

Signs indicating that a recultivation scenario is implemented

- The requirements and technical solutions for the recultivation of the peat extraction site specified in the extraction project of mineral resources has been implemented in the territory;

- The State Forest Service, in accordance with the procedures specified in regulatory enactments, has recognized that a forest stand has been cultivated;
- The planned forest drainage system has been established and is functioning in the area to be restored;
- An act for the completed recultivation work has been drawn and signed by the commission established by the local government construction board.

By fulfilling these conditions, the peat extractor has, for his part, performed the tasks foreseen in the extraction project for mineral resources: to prepare the area for recultivation — the site is ready for the cultivation of a forest. Further actions must be taken by the landowner.

- After a year, the number of grown trees corresponds to the planned number of trees, evenly distributed throughout the area. Trees are viable with steady growth. Species characteristic to dry peat soil or dry mineral soil forests are found in the ground vegetation. The ditch system works, and the drained, well aerated soil layer is at least 0.35 m.

GHG emissions

1. GHG emissions are reduced by reforesting the extracted peat field.
2. By reforesting the peatlands, the mineralization of the peat layer is slower than when they are used in agriculture, therefore, when assessing the climate impact of the further management of peatlands, it is preferable to use them for forestry purposes.
3. After successful reforesting, soil improvement measures (fertilization, liming, soil treatment) are repeated after several decades. This reduces soil temperature and microbial activity, thus slowing down the rate of peat mineralization and reducing CO_2 and N_2O emissions.
4. The impact on GHG emissions has been assessed for a 30-year period following the implementation of the scenario, by assuming that the scenario is introduced in an area where peat extraction has been discontinued recently and ground vegetation has not yet formed, but the topsoil is formed by fertile low or transitional bog peat. Following the introduction of the scenario, GHG emissions will be reduced by 9.7 tonnes CO_2 eq. ha^{-1} per year compared to the initial situation. Total GHG emissions in this scenario over the calculation period correspond to -3.5 tonnes CO_2 eq. ha^{-1} per year, i.e. in 30 years, a net CO_2 attraction is formed in the reforesting area. The calculation of GHG emissions includes CO_2 attraction in living and non-living biomass.

Descriptions of peatland recultivation types have been elaborated within the framework of project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103) with the financial support of European Commission LIFE Programme and the Administration of Latvian Environmental Protection Fund.

A TYPE OF PEATLAND RECULTIVATION: ESTABLISHING ARABLE LAND FOR THE CULTIVATION OF ARABLE CROPS

Ingrīda Krīgere, Inārs Dreimanis, Dace Siliņa, Laimdota Kalniņa, Andis Lazdiņš
Latvian Peat Association
peat@peat.lv

Keywords: peatland, recultivation, arable, afteruse, greenhouse gas emissions.

This type of recultivation involves the transformation and adaptation of former peat extraction sites or recultivated areas into agricultural land for the cultivation of arable crops and the active management of these lands according to the new land use type.

The purpose of the real estate's use — land on which the main economic activity is agriculture, the type of land use—arable land.

Conditions under which this scenario is possible:

- The type of top peat layer: transitional and fen type peat (theremaining thickness of transitional mire type peat <0.25m);
- Thickness of the remaining peat layer: <0.5 m;
- pH level of the top peat layer used: 5.0 - 7;
- Average groundwater level: <0.7-1.0m;
- The area should not be flooded;
- Degree of decomposition of the peat: medium and well-decomposed peat;
- Peat deposit stumps: low coverage of stumps (0.5-2.0%). A high coverage of stumps (2.0-3.0%) and very high coverage (more than 3.0%) will make it difficult to establish arable land.

Suitable for agricultural use are fen (grass) mires, because their soils are rich in minerals, carbonates and nitrogen, their environment is neutral or alkaline (pH = 5.0-7.0). Relatively fertile soils, which are particularly useful for cultivating grasslands (meadows and pastures) as well as for growing vegetables, can be attained by cultivating fen type peat. It is also possible to use a transitional mire type peat under which a fen type peat is shallowly located. Transitional mire peat soils can be slightly acidic (pH<5). Depending on the requirements of the plants to be planted, they may have to be calcined.

For the successful implementation of this recultivation type, it is preferable that the top layer in this area is formed by fen type peat with a higher amount of minerals and potentially higher soil fertility, lower soil acidity. If the creation of arable land is planned at a peat extraction site, where peat extraction has been interrupted without all of the useful peat layer being extracted and transitional mire peat can be found above the fen type peat, then it is recommended that the remaining layer of transitional mire peat is less than 0.25m, which as a result of agrotechnical work would mix with low bog type peat and create more favourable growth conditions for selected plant species.

The recommended maximum peat thickness to be left above the peatland bottom is 0.5m. At peat extraction sites where the extraction has taken place historically and has been discontinued without recultivation of the extraction site, the thickness of the remaining peat layer may be higher. In this case, the possibility of developing the remaining peat deposit layer up to the 0.5m mark, promoting the rational and efficient use of natural resources, should be considered when assessing the economic benefits.

When planning to create arable land in the developed peat extraction site, the location of the drainage system should be such as to guarantee the necessary moisture conditions for the crops in the growing season. In the area of recultivation one must ensure that the average groundwater level is below 0.7-1.0 m.

When transforming the peat extraction area into arable land, preference should be given to creating an open ditch network that discharges surface water faster, catches shallow groundwater and has lower installation and maintenance costs.

As an alternative to arable land drainage, it is possible to set up a drain system, which will result in a more homogeneous humidity regime and make possible the unhindered movement of agricultural machinery and which will not occupy the usable land area.

Completion of recultivation works

The requirements and technical solutions (recultivation work) should be included in the extraction project of mineral resources or in the recultivation plan that has been implemented in the territory. The peat extraction site is prepared for planned land use after peat extraction is completed.

An act should be drawn up and signed in accordance with the procedures specified in regulatory enactments regarding completed recultivation works.

By fulfilling these conditions, the peat extractor has, for his part, performed the tasks foreseen in the extraction project for mineral resources: to prepare the area for recultivation; the site is ready for the creation of arable land and the cultivation of field-crops. Further actions must be taken by the landowner.

Signs indicating that a recultivation scenario is implemented

The planned drainage system in the area to be restored has been created and is capable of providing the optimal water - air regime in the soil for crops cultivation and field treatment.

The field is maintained and various cultivated plants are grown or ornamental plantations are established.

GHG emissions

The impact on GHG emissions has been assessed for a 30-year period following the implementation of the scenario, assuming that the scenario is introduced in an area where peat extraction has been discontinued recently and ground vegetation has not yet emerged, but the topsoil is formed by fertile low bog type peat. Following the implementation of the scenario, GHG emissions will increase by 14,6 tonnes CO_2 eq. ha^{-1} per year compared to the initial situation. Total GHG emissions in this scenario over the calculation period correspond to 20.9 tonnes of CO_2 eq. ha^{-1} per year. The calculation of GHG emissions does not include emissions from fertilizers which, depending on the fertilizer doses used, can significantly increase N_2O emissions from the soil. These emissions are counted in the agricultural sector using the unified calculation method for converting the applied amount of fertilizer into direct and indirect N_2O emissions.

The complex of recultivation measures will promote the reasonable use and management of territories.

Descriptions of peatland recultivation types have been elaborated within the framework of project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103) with the financial support of European Commission LIFE Programme and the Administration of Latvian Environmental Protection Fund.

A TYPE OF PEATLAND RECULTIVATION: CULTIVATION OF LARGE CRANBERRIES

Ingrīda Krīgere, Inārs Dreimanis, Dace Siliņa, Laimdota Kalniņa, Andis Lazdiņš
Latvian Peat Association
peat@peat.lv

Keywords: peatland, recultivation, cranberries, after-use, greenhouse gas emissions.

This type of recultivation involves the transformation and adaptation of a former peat extraction site for the cultivation of large cranberries (*Vaccinium macrocarpon* Ait.)

The purpose of the real estate's use – land on which the main economic activity is agriculture, a type of land use – land under orchards.

Conditions under which the scenario is possible:

- The type of the top peat layer: raised bog peat
- The thickness of the remaining raised peat type: > is not a limiting factor>

- pH values of the top peat layer used: 3.5-4.5pH
- Average groundwater level: on average of 0.5 m
- Average number of days in a year when the area is flooded: cannot be flooded
- Degree of peat decomposition: low decomposed ‹25%

Large cranberries are an evergreen shrub of the evergreen small bush family. The climate of Latvia is suitable for cultivating large cranberries in the extracted peat bogs, where the upper part of the remaining peat layer is formed by raised bog type peat.

To create large cranberry plantations the following must be evaluated:

- The location and functionality of the drainage system in the territory to be restored by ensuring an average groundwater level in the plantation territory of 0.5m. It is necessary to monitor the humidity regime with collecting ditches and gullies;
- There are water bodies (ponds, fire pools, lakes) in the area to be restored or adjacent to it, or there is the possibility of creating water bodies with the required amount of water in the area.
- The condition of the field's surface, because it is important that the surface of the field to be planted is flat, without microlowlands or hills. If the area for large cranberry cultivation does not form a flat surface after completion of peat extraction, surface plating is required to level the field so that the surface slope does not exceed 2%.
- The top layer of the remaining peat should be raised bog peat with a pH of 3.5-4.5. If the pH value of the soil in the planned field of cultivation does not correspond to the implementation of the chosen recultivation scenario, soil improvement and fertilization must be carried out.

In peat extraction areas where peat extraction has been done historically and an overgrowth plant cover has formed, the area must be cleared from overgrowth before planting.

If there are stumps on the surface of the plantation area, they should be removed by removing stems from the fields.

GHG emissions

Large cranberry plantations completely cover the turfy soil surface, which reduces GHG emissions.

The impact on GHG emissions has been assessed for a 30-year period following the implementation of the scenario, assuming that the scenario is introduced in an area where peat extraction has been discontinued recently and ground vegetation has not yet emerged, but the topsoil is formed by infertile raised bog peat. Following the implementation of the scenario, GHG emissions will be reduced by 3.4 tonnes CO_2 eq. . ha^{-1} per year compared to the initial situation. Total GHG emissions in this scenario over the calculation period correspond to 2.9 tonnes of CO_2 eq. ha^{-1} per year. The calculation of GHG emissions does not include emissions from fertilizers which, depending on the fertilizer doses used, can significantly increase N_2O emissions from soil. These emissions are counted in the agricultural sector using the unified calculation method for converting the applied amount of fertilizer into direct and indirect N_2O emissions.

Completion of recultivation works

The requirements and technical solutions (recultivation work) included in the extraction project for mineral resources or the recultivation plan have been implemented in the territory, the peat extraction site is prepared for the planned land use after the completion of peat extraction.

An act has been drawn up and signed in accordance with the procedures specified in regulatory enactments regarding completed recultivation work.

By fulfilling these conditions, the peat extractor has, for his part, performed the tasks foreseen in the extraction project for mineral resources: to prepare the area for recultivation; the site is ready for the cultivation of large cranberries. Further actions must be taken by the landowner.

Signs indicating that a recultivation scenario is implemented

The collecting ditch system is working. The area is free from weeds and other plants. The area to be restored is evenly covered with large cranberry plants, yields are harvested and planted.

Economic use

The area has been transformed after the implementation of the recultivation measures and is used for agricultural production by installing orchards and berry bushes.

There is an economic activity that provides jobs and income.

Descriptions of peatland recultivation types have been elaborated within the framework of project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103) with the financial support of European Commission LIFE Programme and the Administration of Latvian Environmental Protection Fund.

A TYPE OF PEATLAND RECULTIVATION: CULTIVATION OF HIGHBUSH BLUEBERRIES AND LOWBUSH BLUEBERRIES

Ingrīda Krīgere, Dace Siliņa, Inārs Dreimanis, Laimdota Kalniņa, Andis Lazdiņš
Latvian Peat Association
peat@peat.lv

Keywords: peatland, recultivation, Highbush blueberry, Lowbush blueberry, after-use, greenhouse gas emissions.

This type of recultivation involves the transformation and adaptation of former peat extraction sites for cultivating large highbush blueberries (bilberries (*Vaccinium corymbosum)* or narrow-leaf blueberries (lowbush blueberries (*Vaccinium angustifolium* Aiton).

The purpose of the real estate's use — land on which the main economic activity is agriculture, the type of land use — land under orchards.

Conditions under which the scenario is possible:

- The type of top peat layer: raised bog peat
- The thickness of the remaining decomposed or moderately decomposed peat layer: > 0.5 m
- pH values of the top peat layer used: 2.7 - 5.0 for highbush blueberries pH 4.3 - 4.8, for lowbush blueberries pH 4.5 - 5.0;
- Average groundwater level (m): well-aerated soil with a groundwater level of 0.35 to 0.55 m.
- Number of days per year when the area is flooded (days/per year): 0
- Degree of the decomposition of the peat: Low decomposed or medium decomposed

Highbush blueberries are a 1.2 to 2-meter-tall bush, the first harvest is expected in the third year after planting. Low or narrow-leafed blueberries are a semi-bush up to 40 cm high, which begins to give harvest within 2-3 years after planting.

Necessary conditions

The following must be evaluated when planning to establish blueberry plantations:

- Placement and functionality of the drainage system for the area to be restored, providing an average groundwater level in the plantation area on average of 0.35 - 0.55 m. It is necessary to be able to monitor the humidity regime with collecting ditches and gullies together;
- There are water bodies (ponds, fire pools, lakes) in the area to be restored or adjacent to it, or there is the possibility of creating water bodies with the required amount of water in the area.

- The area to be recultivated should not be flooded and there should be no accumulation of water.
- The condition of the field's surface, because it is important that the surface of the field to be planted is flat, without any depressions or hummocks. If the area intended for cultivating bush blueberries does not form a flat surface after the extraction of the peat, surface plating must be carried out by aligning the area of the field so that the surface slope does not exceed 2%. This is necessary in order to make it possible to protect crops against frost in the cultivation process, as well as to provide an appropriate humidity regime, which are the main factors influencing the amount of the expected harvest.

When planning the cultivation of bush blueberries, it should be foreseen that the remaining top layer of peat is made up of less decomposed raised bog type peat with a thickness of at least 0.5 m and a pH of 2.7-5.0. If in the planned field of the plantation, the natural soil pH level is not suitable for the successful implementation of the chosen recultivation scenario, it is possible to perform field soil improvement, which will ensure the necessary growth conditions for the selected plants.

In peat extraction areas where peat extraction has been done historically and an overgrowth has formed, the area must be cleared from overgrowth before planting.

If stumps are fixed in the plantation area, the fields must be freed from stems.

The highbush or large blueberries are planted in furrows. The furrows are made with a 0.50 m rise and are 0.7 m wide. The distance between furrows is 3 m.

The furrows are not formed by planting the narrow-leaf bush blueberries, they are planted in rows one after another with a distance of 0.2 m to 0.4 m from each other and 0.6-1.0 m between rows. When uniformly covering all fields, the recommended planting distances are 0.3 x 0.6 m or 0.3 x 1.0 m.

In both highbush and lowbush blueberry plantation areas, it is advisable to install irrigation systems – both surface (against frost) and drip irrigation. By creating an irrigation system it is possible to fight frost more efficiently, as well as with periods of prolonged drought, and significantly increasing the annual harvest. In order to install an irrigation system, next to the cultivation field of blueberries there should be a place for taking and storing water. The best way to do this is to drain the water from the blueberry fields to the water storage area during precipitation and, if necessary, to deliver the accumulated water through pumping and pipeline systems to the cultivation fields of blueberries.

It is advisable to install an anti-frost early warning system in the field of blueberries.

Climate change

Low-bush blueberry plantations (seedlings), plantations completely cover the turfy surface of the land, which reduces CO2 emissions. CO2 emissions are also diminished in highbush blueberry plantations, especially when grasslands are cultivated between the bush rows. Additional emissions will only result from the use of mineral fertilizers.

The impact on GHG emissions has been assessed for a 30-year period following the implementation of the scenario, assuming that the scenario is introduced in an area where peat extraction has been discontinued recently and ground vegetation has not yet emerged, but the topsoil is formed by infertile raised bog peat. Following the introduction of the scenario, GHG emissions will be reduced by 0.1 tonnes CO_2 eq. ha^{-1} per year compared to the initial situation. Total GHG emissions in this scenario over the calculation period corresponds to 6.2 tonnes of CO_2 eq. ha^{-1} per year. The calculation of GHG emissions does not include emissions from fertilizers which, depending on the fertilizer doses used, can significantly increase N_2O emissions from soil. These emissions are counted in the agricultural sector using a unified calculation method for converting the applied amount of fertilizer into direct and indirect N_2O emissions.

Completion of recultivation works

The requirements and technical solutions (recultivation work) included in the extraction project for mineral resources or the recultivation plan have been implemented in the territory and the peat extraction site is prepared for the planned land use after the completion of peat extraction.

By fulfilling these conditions, the peat extractor has, for his part, performed the tasks foreseen in the extraction project for mineral resources: to prepare the area for recultivation — the site is ready for the cultivation of blueberries. Further actions must be taken by the landowner.

Signs indicating that a recultivation scenario is implemented

- The collecting ditch system is working.
- The area to be restored is evenly covered with a highbush blueberry plantation, yields are harvested, and greenery is maintained.

Economic use

After the extraction of the peat, the territory is used for another type of land use, agricultural production, fruit and berry gardens are created.

The former peat extraction site is engaged in economic activity that provides jobs and income.

Descriptions of peatland recultivation types have been elaborated within the framework of project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103) with the financial support of European Commission LIFE Programme and the Administration of Latvian Environmental Protection Fund.

A TYPE OF PEATLAND RECULTIVATION: PALUDICULTURES

Ingrīda Krīgere, Laimdota Kalniņa, Ilze Ozola, Andis Lazdiņš
Latvian Peat Association
peat@peat.lv

Keywords: peatland, recultivation, water bodies, after-use, greenhouse gas emissions.

Cultivation of paludiculture crops is a relatively new form of recultivation, where cultivated, economically usable plants are grown in the developed peat extraction sites, for whom wet peat soils or peatland are a natural living environment.

The term "paludicultures" is used in the broadest sense to describe and to refer to any cultivated plantation or sowings on periodically flooded or wet peat soils.

Conditions under which the scenario is possible:

- The type of top peat layer: fen (grass) type peat or raised bog type peat depending on the requirements of the cultivated paludiculture.
- The thickness of the remaining peatlayer: depends on the type of paludiculture and the degree of overgrowth of peatland.
- Sphagnum requires at least a 0.1-0.2m raised bog type peat layer, under it the thickness and type of peat layer is not a limiting criterion.
- For cultures that grow in water: reeds, sweet flags, reedmaces, if the peatland is without an overgrowth, the peat layer should not be thicker than 0.1-0.2m, as it will come to the surface in the water. If an overgrowth is formed, the thickness of the peat layer is not critical.
- pH values of the top peat layer used: 3 - 7 (acid up to alkaline, depending on the crop to be cultivated, pH 3-4 for sphagnums, pH 5-7 for bulrush, reeds, reed Canary-grass).
- Average groundwater level, water level: depending on the culture chosen, the area may occasionally flood or even be flooded — sweet flags, reeds (0.5 m below and 2.0 m above the ground), bulrush (0.2 - 1.50 m above the ground), but reed Canary-grass , black alder requires periodic wet conditions (on average 0-0.2 m below the ground). For other plants (e.g. sphagnum) the groundwater level 0m, the area can sometimes be flooded, but not for long periods and the groundwater level should not exceed 0.1m.
- The average number of days in a year when the area is flooded: flooding is allowed or not allowed depending on the type of culture chosen. Flooding is not desirable for fields of planted sphagnum, for other plants the area may be periodically flooded or permanently flooded (reeds). Long-term flooding is not desirable for trees such as black alder.

- Degree of decomposition of the peat: the degree of decomposition of the peat is of secondary importance, but medium decomposed peat (25-30%) is more appropriate. Well decomposed peat above 45% can form a dense layer of peat that can affect the flow of groundwater.

Each culture has a different exclusion criteria. However, they all have one crucial criterion — water availability and characteristics, the ability to raise and maintain water levels.

Other important factors include: the thickness of the peat layer and the type of peat, the chemical composition and structure of the mineral soil. Surface topography is also important for the cultivation of sphagnum moss (the surface should be as flat as possible).

Cultivation is limited by a high coverage of stumps of the peatland.

Paludicultures are grown on periodically flooded or wet peat soils, with the aim of promoting peat conservation and even accumulation, as high-water levels are maintained throughout the year and decayed roots contribute to the accumulation of peat as well as reduce GHG emissions. Surface biomass is made up of reeds, bulrush alders, sphagnum moss and other paludicultures and can be used as a renewable natural resource. Paludicultures can be grown both in degraded low bogs (Bulrush, reeds, sedges, and other plants with neutral or alkaline environments), as well as degraded raised bogs (sphagnus).

Biomass can be produced using conventional reed Canary-grass (*Phalaris arundinacea*), tall Fescue (*Festuca arundinacea*), meadows in the meadow Fescue (*Festuca pratensis*), reeds (*Phragmites australis*) meadow timothy (*Phleum pratense*) and other species. The biomass produced is used in energy, pulp production, as valuable timber, in substrates, water purification, food production, feed, as decorative material, in medicine. Some species are used in pharmacy, such as sundew. Fast-growing trees such as black alder, birch, willow, poplar, etc. are also cultivated for biomass production.

Before starting work, the area to be recultivated should be studied in detail, measurements of peat layer thickness should be made, hydrological conditions of the territory should be evaluated, incl. opportunities to raise and maintain water levels at the required level for each culture. For most of the paliduculture plants, a relatively thin layer of peat (<0.3 m) is sufficient for growing, therefore peat extraction sites where peat has been extracted will be suitable for cultivation, leaving a peat layer from 0.2 m up to several meters thick.

Prior to preparing the territories for the cultivation of paludicultures a detailed study of its hydrological conditions and the possibility of regulating the water regime should be done. Depending on the possibilities of regulating the water level and taking into account the characteristics of the peat layer, it is necessary to choose the appropriate paludiculture. The cultivation of paludicultures can also be beneficial in areas where water levels are controlled by pumps, leaving only excess water.

GHG emissions

The impact on GHG emissions has been assessed for a 30-year period following the implementation of the scenario, assuming that the scenario is introduced in an area where peat extraction has been discontinued recently and ground vegetation has not yet emerged, but the topsoil is formed by infertile raised bog peat. The calculations assume that the plant is sphagnum. Following the implementation of the scenario, GHG emissions will increase by 2 tonnes CO_2 eq. ha^{-1} per year compared to the initial situation. Total GHG emissions in this scenario over the calculation period correspond to 8.2 tonnes of CO_2 eq. ha^{-1} per year. GHG emissions from fertilizers are not included in the calculation, assuming that soil improvers are not used.

According to IPCC guidelines, GHG emissions need not be counted from natural ecosystems, so despite the actual increase in GHG emissions in the paludiculture scenario, this increase in emissions is not counted, but assumed that GHG emission reductions are equivalent to GHG emissions, with the current status of 6.3 tonnes of CO_2 eq. ha^{-1} per year.

Completion of the recultivation work

When the requirements and technical solutions (recultivation work) included in the extraction project for mineral resources or the recultivation plan have been implemented in the territory, the peat extraction site is prepared for the planned land use after completion of peat extraction.

An act has been drawn up and signed in accordance with the procedures specified in regulatory enactments regarding completed recultivation work.

By fulfilling these conditions, the peat extractor has, for his part, performed the tasks foreseen in the extraction project for mineral resources: to prepare the area for recultivation, the site is ready for the cultivation of paludicultures. Further actions must be taken by the landowner.

Signs indicating that a recultivation scenario is implemented

The necessary hydrological regime is provided in the restored area. The vital plant cultivation units, the plants are rooted, successfully hibernated and yield the planned harvest.

Benefits

Optimally, plants form stable stands, their roots and stems cover the surface of the peat, thereby reducing or eliminating CO_2 emissions, as restoration of the hydrological regime in drained mires reduces greenhouse gas emissions by approximately 10-25 t CO_2 from one hectare and ensures long-term carbon capture and storage.

Plants regulate the humidity regime, as well as effectively retain nitrogen, phosphorus and potassium, reducing the flow of these elements into the surrounding water bodies.

The plant cover stops the mineralization and erosion of the peat, prevents the outbreak of fires in the peatland, is a promising place for ecotourism and creates jobs for the local population.

The raw materials obtained from crops grown in the restored areas can be used for the production of different products, as materials for their use (e.g. wood, roots); energy (dry or naturally wet biomass); as feed (hay, grass, flour); in pharmaceutical and chemical industry (various parts of plants).

Descriptions of peatland recultivation types have been elaborated within the framework of project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103) with the financial support of European Commission LIFE Programme and the Administration of Latvian Environmental Protection Fund.

A TYPE OF PEATLAND RECULTIVATION: RENATURALISATION

Ingrīda Krīgere, Laimdota Kalniņa, Inārs Dreimanis, Māra Pakalne, Andis Lazdiņš
Latvian Peat Association
peat@peat.lv

Keywords: peatland, mire, renaturalisation, recultivation, greenhouse gas emissions.

Renaturalisation – a set of activities for recultivation the characteristic vegetation of the mire after the completion of peat extraction, promoting the restoration of the mire's ecosystem. The main purpose of renaturalisation is to restore the functioning of the mire ecosystem, the hydrological regime and vegetation characteristic to the mire.

Conditions under which the scenario is possible:

- The type of top layer of peat (raised, low, transitional): restrictive criterion depending on what type of mire recultivation is planned, because raised bog type vegetation can be restored on raised bog peat, fen type grasses on fen peat, etc.
- The thickness of the remaining peat layer: ≥0.50m for raised bog renaturatosation, ≥0.3m for fen renaturatisation.
- pH values of the top layer of peat: restrictive criterion depending on the type of peatland type planned for recultivation. Raised bog vegetation (sphagnum, etc.) requires pH ≤ 5. If restoring fens, then pH≥ 5.
- Average groundwater level: 0.00m or 0.15m during the summer, the area may occasionally be temporarily flooded.
- Average number of days in a year when the area is flooded: up to 90 days a year

- The degree of decomposition of the peat is not a restrictive criterion.

Renaturalisation is the most appropriate form of recultivation of a peat extraction site if a decision is made on restoring the habitat of the mire and the habitats of the humid-loving plant species that make it.

Renaturalisation as the most appropriate type of recultivation should be considered and implemented as a priority in cases where the peat extraction site is directly adjacent to the relevant habitat type in a specially protected nature area.

There must be a water body (pond, fire pools, lake) in or near the recultivation area in order to have access to the necessary amount of water to ensure the humidity regime for the growth of the bog plants.

The renaturalisation scenario can be successfully implemented if water runoff is limited to such an extent that the water level rises to the surface of the peat extraction field or even above it by temporarily flooding it. In such cases, the effect is like in the purposefully renaturalised peat extraction fields, where the restoration of the mire ecosystem is possible in the long run. Mire plants under favorable conditions spread within a few years, but the vegetation structure and microrelief characteristic of the mire form only in decades.

An important condition for the retention of water is the type of sediment and the permeability of the water under the peat. If ditches reach mineral deposits, as is most often the case of extracted bogs, the result of raising the water level can be difficult to predict or even unsuccessful. In permeable sediments (sand, gravel), the surface water is filtered through the ditch base. Whereas, restoring water to a less water-permeable substrate (clay, dolomite) can be successful.

If the territory to be renaturalised is located directly next to a natural bog or the undeveloped part of the same bog, the bog restoration will be more successful – the donor territories of the mire plants will be closer.

The surface condition of the field to be restored is essential. The field must not be with slopes or hillsides. Otherwise, when the water level is raised, the lowest places will be flooded, but in the higher places the amount of water will be insufficient, and the humidity conditions will not be satisfactory.

If the peat extraction site has been left for decades, it does not have any economic activity and has not developed enough humidity, cotton-grass, heather, birch, pine can grow in it. Tree harvesting is planned in such places. In these types of areas, the top layer of peat is heavily mineralized, so it is advisable to remove it before the groundwater level is raised and level and loosen the surface, which will improve the possibilities of the bog plants being grown.

A The implementation of a renaturalisation scenario is planned without the reintroduction of mire-specific plants

If the water level is raised at the developed peat extraction site, the bog ecosystem can be restored without other targeted activities. The water level is increased by closing the ditches of the drainage system, creating dams or other water level control systems for water regulation.

When planning the renaturalisation of a peat extraction site, it is necessary to foresee the possibility to diversify the microrelief, i.e. to create the relief of the mounds and the lowlands. Monotonous environments hinder the development of species diversity due to the lack of ecological niches (i.e. diversity of conditions).

B The implementation of a renaturalisation scenario is planned with the reintroduction of mire-specific plants

In order to achieve faster result of the recultivation of the mire's ecosystem, the introduction or reintroduction of the mire's plants is recommended. In Latvia's circumstances, this cannot be considered as a priority because the characteristic species under favorable conditions are introduced by themselves. Reintroduction is suitable for small areas.

Cultivating plant species should be chosen according to the conditions — the remaining peat properties and the type of peat. For this purpose, one must choose frequently present, specific to the growth conditions mire plant species, including those observed in Latvia under pioneering conditions and introducing themselves without human assistance in similar circumstances. It is not useful to try to achieve the introduction of sphagnum in neutral, alkaline or weakly acidic mires, where the remaining peat layer is formed by a grass mire type of peat. If it is decided that the plant regeneration will be promoted by the introduction of humidity tolerant plants, in such circumstances herbaceous plant species should be chosen – depending on the environment, species suitable for slightly acidic or alkaline pH conditions.

It should be possible to regulate the water level in the area, as the fields should not dry out during the dry season, but the water level should not be too high during excessive precipitation to prevent it from waving when the wind blows. It is necessary to assess whether it will be possible to raise and hold groundwater at the "0" mark in the area and whether it will be possible to discharge excess water. Water level fluctuations should not exceed +/- 0.03 m from the "0" mark.

Initially, the area to be restored should be leveled and planed. If the area has been left for a long time, it must be cleaned of the vegetation that has formed before it is renaturalised. The top layer of mineralized peat needs to be cultivated, milled or planed because it will be too mineralized. If there are traces of stumps and tree roots in the area, they may not be removed as it does not interfere with the restoration of the bog.

All work processes – the preparation of the area to be renaturalised, obtaining and sowing/planting of donor material, as well as the restoration of the hydrological regime must be carried out in a very short time. Peat after the peat field has been prepared for restoration should not dry out, because then the donated material will not grow in.

Donor material should be immediately transported to the area under renaturalisation after harvesting and should be sown, otherwise it will dry out and lose its properties and ability to grow in. After dispersal of the donor material, the hydrological regime should be such that the water level is “0”.

Donor material is best taken from peat extraction areas in preparation. There is good quality acrylic in full depth and in the whole area. If there are no such bogs nearby, the donor material can be extracted from other natural bogs. After spreading the donor material, it must be covered with reeds. Reeds do not allow the fragments of sphagnum to be inflated by the wind before they can take root. Reeds protect from direct sunlight and help to maintain a humidity regime in the beginning.

Completion of recultivation works

The requirements and technical solutions (restoration work) included in the extraction project for mineral resources or the restoration plan have been implemented in the territory, the peat extraction site is prepared for the planned land use after the completion of peat extraction.

An act has been drawn up and signed in accordance with the procedures specified in regulatory enactments regarding completed restoration works.

By fulfilling these conditions, the peat extractor has, for its part, performed the tasks foreseen in the extraction project for mineral resources: to prepare the area for restoration. Further actions must be taken by the landowner.

Signs that recultivation is successful

There are signs of bog self-renewal, regardless of the type of renaturalisation of the area.

The regeneration of vegetation is indicated by the introduction and propagation of mire plants, which can be observed in the vegetation monitoring plots. The donor's material is alive, rooted and it reproduces independently. In hydrological monitoring, it can be stated that the groundwater level in the peatland is close to the “0” level and has stabilized but not lower than 0.15 m in the summer period. Over the course of five years, the degraded peatland is covered with green vegetation. In fact, there are no open peat areas.

Benefits

Climate change

When restoring natural peatland vegetation in peat extraction sites, greenhouse gas emissions are reduced in the peatland area.

GHG emissions

The impact on GHG emissions has been assessed for a 30-year period following the implementation of the scenario, if the scenario is introduced in an area where peat extraction has been discontinued recently and ground vegetation has not yet emerged, but the topsoil is formed by raised bog peat. Following the implementation of the scenario, GHG emissions will increase by 2 tonnes CO_2 eq. ha^{-1} per year compared to the initial situation. Total GHG emissions in this scenario over the calculation period correspond to 8.2 tonnes of CO_2 eq. ha^{-1} per year.

According to IPCC guidelines, GHG emissions need not be counted from natural ecosystems, so despite the actual increase of GHG emissions in the renaturalisation scenario, this increase in emissions is not counted but assumes that GHG emission reductions are equivalent to GHG emissions, with the current status of 6.3 tonnes of CO_2 eq. ha^{-1} year.

Biological

When hydrological regeneration occurs and the bog plants are introduced, rare and protected species of plants and animals can be introduced in renaturalisation areas. It can serve as an important habitat for birds.

Renaturalised areas will significantly increase biodiversity, and peat formation processes will resume.

Deficiencies

Latvia has not accumulated enough experience of renaturalisation with the reintroduction of mire plants, such a scenario is being implemented in separate test sites with an area not exceeding 0.2 ha.

Restoration of the hydrological regime of the territory to be renaturalised may be technically complicated, time consuming and require considerable financial resources in cases where the establishment of specialized hydrotechnical structures is necessary to regulate the necessary water level.

The introduction of a renaturalisation scenario may be difficult in large continuous areas that are more exposed to wind erosion, characterized by higher evaporation, lack of shaded areas that, at least fragmentarily, protect the peat from strong day-to-day temperature fluctuations, especially in the summer. The surface of the peat is dark, and in summer it is characterized by heavy heating, which significantly inhibits the survival of plants.

Descriptions of peatland recultivation types have been elaborated within the framework of project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103) with the financial support of European Commission LIFE Programme and the Administration of Latvian Environmental Protection Fund.

A TYPE OF PEATLAND RECULTIVATION: ESTABLISHING OF WATER RESERVOIRS

Ingrīda Krīgere, Inārs Dreimanis, Laimdota Kalniņa, Andis Lazdiņš
Latvian Peat Association
peat@peat.lv

Keywords: peatland, recultivation, water bodies, water reservoirs, after-use, greenhouse gas emissions.

This type of recultivation foresees the creation of artificial water bodies in the former peat extraction sites — to install water reservoirs for agricultural, fisheries, recreational or complex use.

It is the most appropriate type of recultivation for the further use of such developed peat extraction sites in areas where the bog has been formed by a water body being overgrown. After peat extraction, the former peat extraction site is flooded with the purpose of utilizing this area for pond management, waterfowl living, biodiversity conservation and/or recreation. Over a longer period of time, if appropriate, management measures are not taken (reed, sedge mowing, etc.), it is expected that the water reservoir will overgrow with herbaceous plants characteristic to mires.

The purpose of the real estate's use — a land of water objects, land use — land under water.

Conditions under which this scenario is possible:

- The scenario is possible if the area is not in the airport protection zone
- The type of top peat layer: not a determining criterion.
- It should be considered that the type of peat that forms the surface of the area to be restored and the thickness of its layer is a partially limiting factor and should be dug away for the successful functioning of the water reservoir. If the remaining peat layer is raised bog type peat, it indicates that the bog has been formed by paludification of the mineral soil and therefore there will be insufficient groundwater supply required for a water reservoir. Precipitation water will not be enough to exist in the reservoir.
- Thickness of the top peat layer: partially determining criterion, if the peatland before the flooding is overgrown, then the remaining peat layer is a partially limiting factor, as it will contribute to the faster overgrowth of the water reservoir, poorer water quality, which in turn will limit its use in water management. It is different, if the water reservoir is designed solely for the protection of waterfowl, then islands can be preserved or specially created for bird nesting. If the peatland before the flooding is overgrown, the peat layer should be dug away, leaving as little peat as possible (maximum 0.1-0.15m) or dug until the mineral soil, as the remaining peat layer can rise to the surface.

- pH values of the top peat layer: not a decisive criterion
- Average groundwater level: it is desirable to have the highest possible level of water (groundwater + surface), which would ensure a stable level in the water body.
- Average number of days in a year when the area is flooded: all year
- Degree of decomposition of the peat: - well-decomposed fen type peat that does not float.
- Composition of the sediment forming the mire base of the area to be restored: restrictive criterion.
    - o Medium and well permeable (sand, clay sand) – this scenario is problematic or impossible if the bottom is made up of water-permeable sediments and does not infiltrate into groundwater.
    - o Low permeability (fine aleirite, clay, sandstone) - is not a limiting criterion. Scenario implementation is possible.
    - o Airtight (clay, dolomite, limestone, marl) is not a restrictive criterion. Scenario implementation is possible.
- Hydrological and hydrogeological conditions of the territory:
    - o Feeding from precipitation (not possible because it does not ensure overflow of the territory all year).
    - o Groundwater inflow into intervertebral hollows (possible).
    - o Bordering with a watercourse whose annual average water level exceeds the height of the surface of the area to be restored (is possible).

The hydrological and hydrogeological conditions of the area to be restored (the type of water supply to the territory) are also an essential precondition. Hydrological conditions are not suitable for the implementation of the chosen recultivation scenario if the main feeding method of the territory is only precipitation.

A pond or pond system is an artificial water body that is classified as a hydrotechnical building according to the normative regulations. When installing a pond, the Cabinet regulations on drainage systems and construction of hydrotechnical structures must be observed. This means that prior to the implementation of the activity, in accordance with the requirements of regulatory enactments, it is necessary to develop a construction plan that regulates the design and construction of drainage systems and hydrotechnical structures.

Water reservoirs are a suitable form of recultivation in areas where the peat layer has been developed up to the mineral soil, then the water will be characterized by a higher degree of mineralization, normal or alkaline pH and other chemical parameters.

It is necessary to perform hydrotechnical calculations on the amount of water entering and its evaporation rate in order to find out in what part of the restored area it is possible to implement the planned recultivation scenario, how deep the reservoir will be and whether the water will cover the flooded area all year round.

In peat extraction sites, where the establishment of reservoirs is planned as a type of recultivation, the development of peat deposit is planned to be carried out as close as possible to the mineral soil. If there is sapropel under the peat, remove the peat until the sapropel sediment and do not carry out loosening or ploughing.

If the area to be restored is to be used for nature conservation measures, mainly as a habitat for waterfowl, the reservoir does not have to be deep and there are no special requirements for water quality. Similarly, if the complete extraction of the remaining peat layer is economically unprofitable or impossible, area flooding measures may be carried out on the remaining peat layer. By implementing such a scenario, the bed of the water body will contain sediments rich in organic substances, which will promote overgrowth of the water reservoir, and possibly a bog in the future.

GHG emissions

The impact on GHG emissions calculations assumes that the reservoir has been formed in an area where a sufficiently thick layer of transitional or fen type peat has left and GHG emissions correspond to the average values in the recultivated area. As an alternative scenario, the preservation of the existing state in the peat extraction field is evaluated. The impact on GHG emissions has been assessed for a 30-year period following the implementation of the scenario. Following the implementation of the scenario, GHG emissions will increase by 7.4 tonnes CO_2 eq. ha^{-1} per year compared to the initial situation. Total GHG emissions in this scenario over the calculation period correspond to 13.6 tonnes of CO_2 eq. ha^{-1} per year.

Signs indicating that a recultivation scenario is implemented

- The requirements and technical solutions included in the extraction project for mineral resources or the recultivation plan have been implemented in the territory or its part and those are related to the recultivation of a peat extraction site have been fulfilled;
- The area to be recultivated, or part of it, is fully covered by water throughout the year, reaching the foreseen level;

By performing the above-mentioned work, the peat extractor has installed a water reservoir, and for this reason has performed the tasks foreseen in the extraction project of mineral resources: to prepare the territory for recultivation. Further actions must be taken by the landowner.

Economic use -

The area is well-kept, its rational economic use continues, while providing recreation and socio-economic aspects.

Biodiversity - Biodiversity is being developed in a previously exploited area. The area provides a home for bird species, a resting place for migratory waterfowl, and a variety of other species. The area is attractive for recreation, it is managed. Depending on the depth of the water, its chemical composition and other factors, the mire's ecosystem will be restored over a longer period of time.

Descriptions of peatland recultivation types have been elaborated within the framework of project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103) with the financial support of European Commission LIFE Programme and the Administration of Latvian Environmental Protection Fund.

TYPE OF PEATLAND RECULTIVATION: PERENNIAL GRASSLANDS

Ingrīda Krīgere, Inārs Dreimanis, Laimdota Kalniņa, Dace Siliņa, Andis Lazdiņš
Latvian Peat Association
peat@peat.lv

Keywords: peatland, recultivation, grassland, after-use, greenhouse gas emissions.

The scenario foresees the transformation of former peat extraction sites into agricultural land with perennial grassland that is regularly mown or grazed. The drainage system must be modified and maintained for the implementation of this scenario.

The purpose of real estate use - land on which the main economic activity is agriculture, type of land use - grassland.

Conditions under which the scenario is possible:

- The type of top peat layer: transitional or fen type peat, thickness of the remaining transitional bog type peat < 0,25m
- The thickness of the remaining peat layer: < 0,5 m
- pH level of top peat layer used: 5.0 - 7;
- Average groundwater level: perennial herbaceous plants for hay 0.70-0.75m, perennial herbaceous plants for grazing 0.80-0.90m
- Average number of days in a year when the area is flooded: the area can be flooded seasonally; it cannot be constantly flooded.
- Degree of decomposition of the peat: medium and well decomposed peat
- Peat deposits coverage with stumps: < 3.0%

The most suitable for agricultural use are Fen (grass) mires, because their soils are rich in minerals, possibly with carbonates and nitrogen, they are less acidic (pH = 5.0-7.0).

For the successful establishment of perennial grassland, the recommended topsoil type for the area to be recultivated is: - fen type peat with higher mineral content and potentially higher soil fertility, lower soil acidity. If the implementation of the relevant recultivation type is planned at the peat extraction site, where peat extraction is stopped without the entire valuable peat layer being extracted, and the transitional mire type peat is found above the fen type peat, its recommended remaining thickness is preferably less than 0.25m, which as a result of agrotechnical work will mix with fen type peat to establish more favourable growth conditions for selected herbaceous plants.

The peat soils of the transitional mires are slightly acidic (pH4-5). If their pH is 4.0-4.3, depending on the requirements of the cultivating culture, they may have to be calcined.

Perennial herbaceous plants are highly productive, relatively inadequate in terms of soil conditions. Many herbaceous plant species are suitable for growing in turfy, wet, flooded areas. The strong root system of herbaceous plants has a positive effect on soil quality, promotes the formation of persistent turf and binds carbon, preserving and increasing organic matter and preventing soil erosion.

Herbaceous plants are energy efficient plants. Their cultivation requires relatively small amounts of equipment, no specialized equipment is needed, traditional agricultural machinery can be used for management.

The most important condition for the implementation of this recultivation type is a proper assessment of the hydrological conditions of the recultivation area. It is necessary to assess: the water inflow to the territory, the composition of sediments forming the bog's base, the technical condition of the drainage network of the peat extraction site (collecting ditches, runoffs) and the hydrotechnical structures (culverts) created on it, the state of the drainage system of the peat extraction site and its suitability for the planned land use.

The layout of the planned drainage system must be such as to guarantee the optimum air and humidity conditions for the cultivated herbaceous plants during their vegetation, and at different stages of their development. These conditions are achieved by planning the depth and spacing of the existing or rebuilt sediment ditches. When planning the placement of sediment ditches, the thickness of the remaining peat layer and the composition of the sediment under the peat should be taken into account. This will make it possible to determine the optimal depth and distance of the ditches or drains.

By converting peat extraction sites into herbaceous plant areas, land drainage with drainage or open ditch network should be planned for land use.

Planning the drainage of the site with an open ditch network will result in faster discharges of surface water from the area, capture of groundwater, lower installation and maintenance costs.

When drying the area by installing a drainage system it is possible to achieve more even humidity conditions, ensuring unhindered movement of agricultural machinery, not occupying usable land areas, deeper plant roots in drained areas and the use of nutrients there, creating more homogeneous areas that facilitate grazing, herding, etc.

One of the additional measures in planning herbaceous plant areas at peat extraction sites, where peat extraction has been discontinued is to determine the coverage of stumps on the peat layer. Peat extraction sites with a high coverage of stumps will be heavily burdened by the use of the area for intensive agricultural activity. Field evacuation, stump and root harvesting will have to be carried out, as well as the agrotechnical processing of difficult fields.

If necessary, field soil improvement and fertilization is carried out, which will ensure the necessary growth conditions for the selected plants.

GHG emissions

The impact on GHG emissions has been assessed for a 30-year period following the implementation of the scenario, assuming that the scenario is introduced in an area where peat extraction has been discontinued recently and ground vegetation has not yet emerged, but the topsoil is formed by fertile transitional and fen type peat. Following the implementation of the scenario, GHG emissions will increase by 8 tonnes CO_2 eq. ha^{-1} per year compared to the initial situation. Total GHG emissions in this scenario over the calculation period correspond to 14.3 tonnes of CO_2 eq. ha^{-1} per year.

Completion of recultivation works

The requirements and technical solutions (recultivation work) included in the extraction project for mineral resources or the recultivation plan have been implemented in the territory, the peat extraction site is prepared for the planned land use after the completion of peat extraction.

An act has been drawn up and signed in accordance with the procedures specified in regulatory enactments regarding completed recultivation works.

By fulfilling these conditions, the peat extractor has, for his part, performed the tasks foreseen in the extraction project for mineral resources: to prepare the area for recultivation - the site is ready for the cultivation of herbaceous plants. Further actions must be taken by the landowner.

Signs indicating that a recultivation scenario is implemented

The planned drainage system in the area to be restored has been created and it is capable of providing the optimal water - air regime in the soil for herbaceous plant cultivation and field treatment.

High quality perennial herbaceous plants have been formed in the area to be restored.

Economic use

The area has been transformed after the implementation of the recultivation measures, it is included in organic soils and becomes an intensive agricultural area that gives further economic and social benefits.

Deficiencies

Perennial herbaceous plants are an area intensively used in agriculture and is a GHG emitter.

Descriptions of peatland recultivation types have been elaborated within the framework of project “Sustainable and responsible management and re-use of degraded peatlands in Latvia” (LIFE REstore, LIFE14 CCM/LV/001103) with the financial support of European Commission LIFE Programme and the Administration of Latvian Environmental Protection Fund.

OTHER CONFERENCE POSTERS

ALTERNATIVE USE OF PEAT

Edgars Ameriks
Peat Researcher / Artist
www.edgarsameriks.com

Traditions and their significance

Our future depends on our level of responsibility, knowledge, skills, determination, and culture. Over the course of more than 10 years gaining experience in research and innovative use of peat, new traditions were born in Latvia that are unique and to be found nowhere else.

The opportunities our land provides should be studied and appreciated to facilitate future development. The use of peat in art and design has defined a wide range of brand new opportunities for application and research principles. Peat has defined a new culture that requires a more deeply evaluated and conscious attitude to the developments of our time.

Peat Workshop. Riga, 2018

Art and innovations

Art and innovation are in absolute harmony and they are dependent on each other. Creative work can change perceptions and experimental and practical aspects drastically. I believe that innovation cannot be planned and defined ahead. Instead it should be discovered and practically substantiated step by step. An artist, as opposed to a scientist, works on an emotional level and tends to achieve emotional enjoyment. Those are basically natural processes that facilitate research which is dependent on emotion.

The peat extraction and swamp management industry of today is still quite primitive. It is fairly recent and based on historically accepted principles that are stagnating and do not match the age. Historically, the experience of the West and the Soviet Union point to an unwelcome scenario in swamp and peatland management. Latvia is at a starting point to become a role model in the management of swamp and peat extraction areas. In this industry innovation can only be anticipated and developed in carefully and responsibly prepared areas.

Restaurant L' Ecorce Concept Store / France / Courchevel 1650 (Moriond) / 2016

Alternative use of peat

Ever since 2008 I have been using peat in my creative process and have got to know this unique material from a whole different perspective. Alternative ways of using peat were created – from geological research to preparation work. Ways to use peat in the production of premium products:

- Peat coated plywood
- Peat composite materials
- Decorative peat plaster

were studied.

These materials have been used in a number of projects in Latvia and abroad, their practical endurance is inspected. It has been proven that peat may be used in the production of finished materials, furniture and decorative items.

In order to use the full potential of peat as a resource it is extremely important to assess the swamp industry as a whole and define its strategy on a national level. Peat extraction should be supported by products with the highest added value and adapted to consumer demand. Currently, peat extraction areas have been prepared experimentally and technologies have been developed specifically for this alternative use in Latvia.

Education and culture

It surprises me how it is still possible to discover a natural resource with potential that has not yet been tapped into. Technologically it could have been possible centuries and even millennia ago, however, the human mind can only grasp the true meaning and value of nature today. It points to the cultural level of the 21st century that encourages an in-depth study of this industry. Nowadays the survival instinct has changed and it is in balance with nature.

Peat Art Studio / Gallery / Riga / 2018

In order to prepare peat material for use in art and design all the underlying processes had to be acquired anew. There was no advice or educational information available. These circumstances define a brand new and unique work culture that may be acquired only through practical learning from mistakes. Public opinion plays a significant role in this process. Educational cultural events are organized to this end. Peat allows one to learn about nature and technical skills. This material can be processed easily and fast using only one's skills and manual work. This technique is especially effective and suitable for the new generation development. The phenomenon of peat is a never-before-seen contrast determined by its texture, content and qualities. Moreover, there is currently a lack of understanding in society regarding the material itself and its origin, consequently new knowledge about our rich natural resources and their influence is imparted.

The influence of peat on art is especially significant. The unique material palette is defined as the artist's original technique and raises great interest in the process as a whole. Conceptually all artwork made from peat is primarily positioned as the human understanding and responsibility towards nature. The pieces are very fragile and the slightest physical touch breaks them down. It means this artwork can be affected negatively by human beings just like nature. These items show one's cultural level and attitude.

Mission

To develop the significance of peat and its impact on education, culture, science, and art. The philosophy of peat sets higher standards for subordinated fields and one's responsibility. Participation in international projects and events clearly points to the impact of peat as a significant resource in education and culture. The rapid development of peat innovation shows that a considerable contribution is required for the development of the industry. In the context of Latvia, the potential of this resource should be assessed and a strategically substantiated action plan should be developed.

External links

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- https://www.discoverthepeat.com

CHARACTERISTICS OF DEPOSIT AND WATER CHEMICAL COMPOSITION AND POLLUTION FROM LAUGA BOG

Jānis Dreimanis, Laimdota Kalniņa, Līga Paparde
University of Latvia, Faculty of Geography and Earth Sciences
janis.dreimanis85@inbox.lv

The mire is an important part of the water cycle in nature as it accumulates water, thus affecting the microclimate and hydrological regime of the surrounding area, and also cleans up contaminated rainwater and surface waters. One of the drivers of the degradation of the Lauga Bog is the drainage system, which influence bog waters runoff. There is also a significant impact of the agriculture processes, that is, the cultivation of large cranberries. It is one of the methods of rehabilitation of former peat extraction fields, which resulted increased in the bog water level with blockage of drainage system by dams built on ditches. In some cases dams cause a problem because they can be damaged, insecure and unsafe, and built using inappropriate materials, including railway track sleepers and polyethylene bags, which are potential environmental pollutants (DAP 2017).

By intervening in the natural hydrological regime of bogs, for example, when ditches are installed, intensive drainage of water from the bog is achieved, the balance between the accumulation of atmospheric precipitation in the bog and the amount of natural runoff from the bog is disrupted. As a result of changes in the hydrological regime of the bog, not only the hydrological and ecological conditions in the bog are disturbed, but also the condition of the surface water courses supplemented by the bog waters (Heather et al. 1996). Therefore, measures for the restoration of the hydrological regime of the bog are important not only from the point of view of the conservation of the bog habitats, but also to ensure the natural hydrological and ecological conditions of the surrounding area (Nomals 1930). At the same time, it should be taken into account that the restoration of the hydrological regime of the bog is an interference in the already changed water regime. Before taking such measures, it is necessary to investigate in detail the disrupted regime, to predict the expected results of the restoration measures and only then to decide on the necessity of such measures.

The aim of the research is to find out, characterize and compare the chemical composition and pollution of bog water and sediments in various parts of the mire.

Field studies, including geological drilling and sampling for laboratory analysis will be carried out to determine the chemical composition of the bog water and sediment and to carry out pollution characterization. Laboratory analysis include: determination of chemical composition by liquid-gas chromatograph and metal composition determination. Using computer software (*MS Excel, GCMS Solution Version 4.3*, etc.), data processing and visualization, as well as interpretation of results will be performed.

Comparison of chemical composition analysis results from the bog deposits and water, allows to conclude that peat contains significantly higher amount of pollutants, including metals, than bog water, which indicates peat higher absorbing properties.

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CULTIVATION OF LARGE CRANBERRIES IN PEAT BOG IN LATVIA

Dr.agr. Līga Vilka, Dr.agr. Dace Siliņa
Latvia University of Life Science and Technologies, Faculty of Agriculture
liga.vilka@gmail.com, dace.silina@llu.lv

Keywords: large cranberry, growing technology, peat bog.

Introduction

The large cranberry (*Vaccinium macrocarpon* Ait.) is evergreen *Ericaceae* plant and approximately 200 years has been cultivated in North America (since 1816). In the seventies of the 20th century Dr.biol. A. Ripa introduced large cranberries in Latvia, but first plantations started to plant more than 20 years later (at the end of the 1990s). For cultivation of large cranberries must fallow up the basic rules: a sour environment (soil pH 3-4,5) and a high organic content must be provided. In North America, large cranberries are cultivated mostly in mineral soil but in Latvia uses our resources – peat bogs. In recent years, producing cranberry plantations exceed 170 ha in Latvia, of which only approximately 2 ha have been planted using basis of mineral soil but in *upper layer* used peat and sawdust, mainly plantations are in peat bogs. The berries of *Vaccinium macrocarpon* contain many vitamins and minerals (C, B1, B2, B3, Fe, Na, K, Ca, etc.) and other biologically active substances (antocyanins, flavonoids, pectin, benzoic acid, etc.). It has been scientifically proved that large cranberries are more valuable than local small cranberry (*Vaccinium oxycoccus*).

Aim

To compare growing conditions of large cranberry in North America and Latvia**.**

Methodology

The monographic method (literature studies) was used to find out different growing conditions of large cranberry in North America and used results from investigations of Faculty of Agriculture (Latvia University of Life Science and Technologies), when few years ago were inspected plantations – growing conditions, diseases and insects in plantations of large cranberry in Latvia.

Results

The cranberry growers in North America create artificial beds – "bogs" using basic of any type of mineral soil (sandy loam, loamy sand or clay) and 20-30 cm organic soil layer (peat, muck, renovation sediments, yard compost, decomposed wood waste). Usually cranberry plantations are near water bodies, because water is necessary all the year, mainly in North America. There are water confining layers (dams) and ditches, where is possible to hold a flood to cover the cranberry vines at harvest and usually before winter (protect from frost). Therefore, cost for create new plantation is very high (48 500–74 000 USD). The Latvian growers for creating new plantations, use areas in raised bogs (peat moss) after peat extraction, if a peat layer is at least 50-60 cm after peat cutting. The cranberry fields in Latvia could be a more stable, if there would be layer of mineral soil, but in Latvia sand pH is very high (pH >7) and in sand has many seeds of weeds, therefore sand in peat bog is not usable.

Like in North America, also in Latvia the field before planting must be specifically prepared: ditches, dams, roads, etc., remove upper layer (roots of trees or forest plants), if it is necessary. The fields must be even, but with a slight slope towards the edges of the field to drain the excess water.

Around the field, there must be a bigger ditch, where can regulate a level of water. Along the edges of the dam surface, 4,5 m wide roads shall be constructed from the mineral soil, at a height of at least 0,75 m above the cranberry field, but in North America the dam high is 2-3 m, because there must hold a water over the cranberry vines and after freezing, can drive by tractors. The cranberry fields in North America and Latvia consists of several smaller fields (0,4-0,5 ha) and between smaller fields are 0,6-1,0 m deep ditch (width 1,0-0,5 m). The level of groundwater should be 0,4-0,6 m. The large cranberries tend to suffer more from a moist than dry soil conditions. Scientists have observed that the level of groundwater during vegetation can affect a yield.

The sprinkler irrigation system is necessary after planting to provide a better rooting of new plants, while in the coming years to protect plants from frost in spring and autumn, as well as in summer hot weather (for plant cooling). In North America they use sprinkler system also for application of chemicals (chemigation). In cranberry plantations in USA mainly have 15 – 16 sprinklers in a row (14 m between rows), but in Latvia between sprinklers have distance 15 × 18 m.

The best time to create new cranberry plantations is beginning of summer (till middle of June). Before planting of cranberry vines, the surface of the soil is crushed, basic fertilizers may also be incorporated at the same time. For planting mainly in North America and Latvia use vines (15-25 cm long sections) from older plantations but there are also disease-damaged vines (uprights too) which increase the incidence of diseases to uprights, but when plants will start to produce a berry, berry rot will develop on them. For one hectare of new field requires 2,5-3 t of large cranberry vines or an average 30 plants per m^2. The distance between plants is approximately 5×10 cm. The vines shall be planted so deep as to remain 2,5 cm above the ground from the cut sections. In peat soil, the vines are harder to stuff into soil, so can a strew with a 2-3 cm thick layer of peat or sawdust. If necessary, can roll or the vines incorporate with a cutter. To provide a formation of new roots, in USA use flood, for a twenty-four hours the water is until surface of the soil, but can use sprinkler irrigation system as well.

Rooted cuttings can also be used for planting, then per hectare will need 20 000 plants, but the cost will be higher. None plant nursery in Latvia can offer rooted cuttings or rooted plants for creating a new cranberry plantation. If the vines are used for planting, during the next year roots and some vines and uprights will be formed. The vines will be formed also in the second year and perhaps can expect the first yield (0,5-1,0 t ha^{-1}). In the third and fourth year, the yield could be 3-5 t ha^{-1}, but below 15-40 t ha^{-1}. In Wisconsin (USA) also yields are much higher: 20-40 t ha^{1}. The yield potentially obtainable is 56t ha^{-1}.

The optimal soil for large cranberry is acid - pH KCl 4–5 (can grow also at pH 3,9–5,9).

The cranberry growth and development are not particularly affected by temperatures ranging from 21 to 32˚C, but necessary 110-150 days without frosts. The growers in USA have observed, the yield of cranberry is lower in years after extremely cold or hot weather conditions. If the average air temperature in April is higher than 6,1˚C and 11˚C in May, good cranberry yields are expected. If the air temperatures in May and June are 10-18,3˚C, the yields will also be good, but if in October or November maximum daily temperature is below -3,9˚C, the yield will be low in next year.

Approximately 200 large cranberry varieties have been created in North America, of which three 'Stevens', 'Bergman', 'Ben Lear', less 'Pilgrim', 'Franklin', 'Early Black', 'Howes' and 'Lemynion' are grown more frequently also in Latvia. In Latvia, A. Ripa has bred several hybrids. Only 7 varieties are registered – 'Kalnciema Agrā', 'Kalnciema Tumšā', 'Kalnciema Ražīgā', 'Septembra', cross-species hybrids of cranberry and lingonberry - 'Dižbrūklene', 'Salaspils Agrā' and 'Tīna'. The Latvian varieties have a shorter vegetation period, a harvesting time is earlier compared to American varieties, while the size and yield of berries are similar to the imported varieties of large cranberry.

For reaching a high yield, is necessary ensure the optimal growth conditions for cranberries all the year and year by year: balanced fertilizing, control of weeds, insects and diseases, vine cutting, watering, mulching, etc.

The disease control is very import in North America, because many pathogens can cause upright dieback, field rot and storage rot of berries as well. In North America is not possible to grow cranberries without fungicides. In Latvia, the incidence of cranberry diseases is low, but 9 pathogens were detected, and they are common in North America as well. Mostly in older plantations some fungicides are used in Latvia. Only three fungicides for using in cranberry plantations are registered in Latvia: Candit (active ingredient kresoxim-methyl 500 g kg^{-1}), Signum (active ingredient pyraclostrobin 67 g kg^{-1} and boscalid 267 g kg^{-1}). Since 2018 one biological product Serenade Aso (*Bacillus subtilis* QST 713, 13.96 g l^{1}) is registered. In Latvia is necessary an investigation to find out the most effective time for fungicide applications. The fungicides should be used as little as possible in peat bogs in Latvia.

In North America, more than 20 fungicides are registered for disease control in cranberry plantations, some of them can use even 3 days before harvest, because more than 150 pathogens are known in North America, which cause damages for uprights, blossoms, leaves and roots, but mainly berries (field rot at harvest and storage rot after harvest). The 32 pathogens can cause fruit rot in North America, most common are

10–15 of pathogens. The incidence of field rot can reach 80-100% in Massachusetts and New Jersey, if during the season no fungicides are used.

More than 10 insects can cause serious damages in cranberry plantations in North America, one of them is cranberry tipworm (*Dasineura vaccinii*) what is also found in plantations in Latvia. No insecticides are registered in cranberries in Latvia, but more than 20 insecticides are in USA.

The issue of weed control is more important than insects in Latvia. No herbicides are registered in cranberry plantation in Latvia. Weeds from plantations are removed mechanically by hand, what is physically very hard work. In USA 18 different herbicides can use in cranberry plantations.

The are other methods, how to reduce the damages and protect the cranberries under anaerobic conditions the most part of weed seeds, insects and pathogens are died. The mulching, sanding and flooding can reduce the applications of pesticides in cranberry plantations in North America and Latvia as well but the investigations of this are necessary in Latvia.

From beginning of September (early varieties) to end of October (late varieties) is harvesting time for large cranberries in Latvia. The Latvian growers use dry-harvesting method, berries are picking by hands or use combines. During a day using specials combines for cranberries can harvest 0,4 ha of area, but 20% of berries left on field. In North America, where plantations are created in artificial bogs, there use wet-harvesting method. The field is flowed at a height of 40-50 cm and hold a water for many days covered the cranberry vines. The special combine is plucked the berries and then berries come to the surface of the water. Then merged the berries together and, by a conveyor, the berries are bundled into trailers and transported to a warehouse or processing plant. As a berries are in water for several hours or days, during this time a large part of the berries are infected by diseases, so the berries cannot store in a fresh way after the wet- harvesting method, berries should processed or freeze.

During a few days after harvesting, the number of rotting berries and mechanically damaged berries increase rapidly, and it is significantly more than after dry harvesting.

In comparison with frequency of using the pesticides in cranberry plantations in USA, cranberries in Latvia can cultivate using a minimum necessity for fungicides than in North America, so cranberries which have grown in Latvia are healthier.

Conclusions:

- The climate and growing conditions are suitable for large cranberry in Latvia and berries are healthier than grown in North America.
- Latvia is the only country in the European Union where large cranberry is cultivated, this would be good export opportunities.
- In Latvia is needed studies to improve cultivation technologies of large cranberry to increase the yields as North America.

EU PROTECTED MIRE HABITAT MAPPING AND QUALITY ASSESSMENT BY AIRBORNE REMOTE SENSING DATA

Rūta Abaja, Dainis Jakovels, Jevgēnijs Fiļipovs, Juris Taškovs, Gatis Eriņš
Institute for Environmental Solutions

Various reasons require precise habitat mapping and quality assessment. For European Union countries it is obligatory each sixth year to report of EU protected habitat distribution and their quality. Habitat mapping and quality assessment is important for habitat restoration actions to monitor the habitat improvement results and for evaluation of human impact on nature values. Mostly, habitat mapping and quality assessment is done by habitat experts in field studies. However, mire habitat assessment in field studies can be challenging and time consuming due to habitat complexity especially for large peatland ecosystems. Remote sensing data analysis has great potential to ease and shorten the process, reduce subjectivity of various habitat expert decisions or experience level and increase the result accuracy. Satellite remote sensing techniques has already demonstrated their potential to establish the extent of peatlands, their elevation and topographic characteristics, the land use/land cover change history, the diversity of the vegetation, the fire disturbance impact and various measurements associated with the atmosphere, such as emissions, smoke and air quality (Tansey 2018).

The study aim was to develop standardised method for EU protected mire habitat mapping and quality assessment based on airborne remote sensing data analysis. The method potentially could ease, shorten and improve accuracy of habitat expert field work to map and assess mire habitats.

Five EU protected habitat types was studied in two peatland areas in Latvia during 2014:

1. Mežole Nature Reserve (7110* Active raised bogs; 7120 Degraded raised bogs still capable of natural regeneration; 7140 Transition mires and quaking bogs);
2. Lake Engure Nature Park (7210* Calcareous fens with Cladium mariscus and species of the Caricion davallianae; 7230 Alkaline fens).

During vegetation season 2014 high resolution airborne remote sensing data was collected over study areas (10th of July in Lake Engure Nature Park and 25th of July in Mežole Nature Reserve) with airborne surveillance and environmental monitoring system (ARSENAL). ARSENAL is aircraft equipped with hyperspectral data sensors, LIDAR and high resolution visual camera. For vegetation analysis the most informative spectral bands of visible and near infrared spectral region were obtained. LIDAR data was used to estimate vegetation structure. Visual, high resolution images were acquired for validation purposes and sample data collection in field expeditions. On each study area one field expedition that consisted of habitat expert with remote sensing data usage experience and several voluntary students of nature sciences was organised for reference data collection. Experienced mire habitat expert Liene Auniņa prepared list of criteria for habitat mapping and quality measures.

The remote sensing data analysis succeed with two habitat maps of 7110* and 7140 habitats and following maps of mire habitat quality measures: reductions of terrain, classified tree height, density of three and shrubs, raised bog micro-relief structure, open water, classification of coniferous and deciduous trees and maps of specific indicator species such as *C. mariscus* and *Schoenus ferrugineus*.

The created maps of mire habitats or their quality measures were compared with previous habitat maps made by habitat experts. The comparison indicated that the remote sensing data method is suitable and accurate for open mire landscapes to detect habitat and mire structure spread. It detected analysed species highly accurate and therefore can help to define more precise habitat borders. Disadvantage of the method is detection inability of ground vegetation under tree cover. However, advantage is precise mathematical calculations of tree cover, high and the structure spread which is usually done by habitat expert guess in field conditions. Such expert measure cannot be repeatable, remote sensing data analysis allow to standardize, repeat the measure and the same data analysis and calculation method to apply for another peatland which gives more accurate comparison. The developed method can improve accuracy of habitat mapping and quality assessment and significantly ease, shorten field job of habitat experts and could be cost-effective especially for large, complex peatland areas. The developed airborne remote sensing method for habitat mapping and quality assessment is adjustable also for other habitat types.

The study was part of a project "Inovatīvas attālās izpētes metodes adaptēšana ES nozīmes aizsargājamo biotopu kartēšanai un stāvokļa novērtēšanai" (No. 1-08 /159/ 2014) that was supported by Latvian Environmental Protection Fund.

EVIDENCE OF CLIMATE CHANGES IN LUBĀNS WETLAND DEPOSITS: EXAMPLE OF SŪĻAGOLS AND ASNE SITE

Līga Paparde, Laimdota Kalniņa, Jānis Dreimanis, Aija Ceriņa
University of Latvia, Faculty of Geography and Earth Sciences
liga.paparde@gmail.com

Key words: Macroscopic remain, loss on ignition, paludification, lake sediments.

Introduction

The research area is located in the Austrumlatvija (East Latvia) Lowland, Lubāns Plain and Lubāns Wetland. The characteristics of Lake Lubāns are its complicated geological structure, hydrographic network and large areas covered by peatlands. Wetland area is also rich with Stone Age settlement sites. Palaeoclimate and palaeogeographic condition changes have influenced palaeovegetation composition and sediment accumulation processes during the development of Lake Lubāns.

Research about Sūļagols and Asne took place in overgrown and paludificated areas of ancient Lake Lubāns. During the late glacial Lubāns palaeolake was at least three times larger in size as in nowadays. Around ancient and present days lake's shores and many nearby rivers many Stone Age settlements have been discovered and 24 of them are nationally protected archaeological sites (Loze 1990). Researches about any archaeological site's environmental changes are significant to obtain overall understanding of geological development and palaeoenvironmental changes during ancient lake shore overgrowing processes peatland formation. The aim of this research is to find out evidence of climate changes during the formation of Sūļagols Bog and Asne Fen which characterize diverse development conditions.

Data and methods

During the research different types of data and materials were collected and used, including sediment samples obtained during field works, author's prepared cartographic materials, performed laboratory analysis and visualised results in corresponding diagrams and charts. In addition to get samples for further investigations during field works geological coring and probing was carried out. All sediment monoliths were well obtained, documented and transported to the laboratory of Quaternary Environment at the University of Latvia.

A combination of different laboratory methods like loss on ignition and macroscopic remain analysis was used to get the best results. Loss on ignition analyses of the Quaternary lake sediments provides an opportunity to investigate changes in the past environment. Curve fluctuations in diagrams indicates water level fluctuations, sediment accumulation condition changes, lake shore overgrowing and paludification processes. Loss on ignition analyses was used for understanding of sediment composition, to estimate ratio of organic, mineral and carbonate matter. With these method two geological cores were analysed: Sūļagols – U1 and Asne – U1 with a total length of 6.0 m of sediment samples. Each sediment monolith was analysed with 1 cm accuracy, meaning 600 samples in total.

Macroscopic remain analysis reveal important information about changing local palaeovegetation and palaeoclimate. Results of this method also give evidence about early human impact on vegetation and the beginning of agriculture (Paparde et al. 2017). Samples from two sediment cores were analysed: Sūļagols – U1 and Asne – U1. In total 120 sediment samples with 5 cm intervals were studied by macroscopic remain analyses.

Results

According to the results of loss on ignition analyses, changes in percentage values of carbonates, mineral and organic matter are indicating sediment accumulation condition changes in the southern (Sūļagols) and western (Asne) part of Lake Lubāns. Depending on the changes in sediment composition four zones (I-IV) were subdivided for Sūļagols and also four for Asne. Both borehole results for this method show similar tendencies.

In both boreholes zone I is represented by highest mineral matter content – fine sand and clay. Possibly these sediments accumulated during the late glacial. Zone II represents sharp increase of organic matter that shows the evidence of warm climate conditions and rapid development of vegetation. Zone III is dominated by peaty gyttja and peat where organic matter keeps increasing. That may have been influenced by fluctuations of lake water levels. While zone IV is dominated by peat that shows the evidence about intensive lake's overgrowing and paludification processes.

Based on macroscopic remain analysis results borehole Sūļagols – U1 and Asne – U1 in general also show similar tendencies. The smallest amount of macroscopic remain variety was found at the bottom of the core while the biggest – at the top. The lowest sediments in both sites contain similar remains of lake flora and fauna. Aquatic plant and animal remains were found: cattail *Typhaceae*, moss mite *Oribatida*, sponge *Porifera* and insect *Insecta*. Covering sediments are more rich in organic matter that represents rapid increase of aquatic plant and animal variety. It is represented by *Typhaceae*, water lily *Nymphaeaceae*, sedge *Carex*, sorrel *Rumex*, water flea *Cladocera*, ostracod *Ostracoda* and *Porifera*.

The middle part of sediment section is characterised by the biggest variety of macroscopic remains. Mostly this interwal is dominated by aquatic plant and animal remains but also dryland plant seeds were found. In both sections *Typhaceae*, rush *Juncus*, arrowhead *Sagittaria*, water-plantain *Alisma*, buzzer midge *Chironomus*, fungus *Fungi*, *Porifera*, *Cladocer*a and charcoal was found. Also many water chestnut *Trapa natans* remains were found in Asne – U1 borehole sediments. Upper part of a section is represented by typical bog and fen macroscopic remains, like moss *Sphagnum*, fungus, wood, leaf and charcoal remains.

Conclusion

- The results of sediment studies in southern and western parts of Lake Lubāns allow to find out changes in sediment accumulation condition dynamics and vegetation caused by climatic changes.
- Loss on ignition analyses results show that in lower part of both sections sediment composition is dominated by mineral matter. Differences are only in larger carbonatic content in the Asne section.
- The results of loss on ignition analysis show that in all investigated sections in the upper layer the amount of organic matter increases, which is related to coastal overgrowing intensification processes in the surrounding areas of nowadays Lake Lubāns.
- Macroscopic remain analyses results represents changes in aquatic and coastal species that have been influenced by palaeoclimate variations and palaeohydrological regime revealing changes from lake conditions to peatlands.

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INNOVATIVE METHOD OF GREENHOUSE GAS EMISSION ASSESSMENT FOR PEATLANDS BASED ON REMOTE SENSING DATA AND GEST ANALYSIS

Rūta Abaja[1], Jevgēnijs Fiļipovs[1], Līga Strazdiņa[2], Māra Pakalne[2], Dainis Jakovels[1]

[1] Institute for Environmental Solutions

[2] University of Latvia

ruta.abaja@videsinstituts.lv

Peatlands account for only 3% of terrestrial surfaces worldwide, but they store nearly 30% of the soil carbon thus playing significant role in global climate mitigation. Knowing amounts of carbon stored and emitted through both natural and human induced processes from model-areas, data can be extrapolated to wider regions, e.g. country borders. Consequently, the importance of peatlands to the total carbon budget of individual countries can be evaluated. Direct greenhouse gas (GHG) emission assessment methods are expensive and time consuming, especially for peatlands. Soft and wet soil conditions burden carriage of the expensive GHG assessment equipment in peatlands. The commonly used direct GHG assessment methods are complicated to use for large and complex peatland ecosystems where are various processes and habitat types. It is approved that GHG emissions are related to particular vegetation type on peatlands that indicates also the natural or human caused environmental processes like water level, nutrient availability, etc. Based on this principle in 2008 in Germany for first time was developed peatland vegetation classification approach – Greenhouse Emission Site Types (GEST) according to particular GHG emission measures (Couwenberg et al., 2008, Couwenberg, 2011). Remote sensing (airborne and satellite) techniques provide large area coverage in short time and possibility of automatic data processing. High resolution remote sensing data has demonstrated their potential to assess various vegetation types, habitats, their structure and even quality for different ecosystems.

The study aim was to combine high resolution spectral and LIDAR data with GEST analysis approach of peatland vegetation to develop new method for GHG assessment as an alternative and potentially less resourse consuming GHG assessment method.

The study included four different peatland areas in Latvia:

1. Pēterezera Inter-dune Mire and Kukšupes Inter-dune Mire in Slītere National Park (include habitats: fens; 7140 Transition mires and quaking bogs; 7110* Active raised bogs);
2. Lake Engure Nature Park (7210* Calcareous fens with Cladium mariscus and species of the Caricion davallianae; 7230 Alkaline fens);
3. Sudas-Zviedru Mire in Gauja National Park (7110*, 7120 Degraded raised bogs still capable of natural regeneration; 7140);

4. Madiešēnu Mire and Namītēnu Mire in Augstroze Nature Reserve (7110*; 7120; 7140).

Remote sensing data of the project areas was collected in 03.06.2018. with airborne surveillance and environmental monitoring system (ARSENAL) that includes aircraft equipped with hyperspectral data sensors, LIDAR and high resolution visual camera. From the hyperspectral data, 27 most informative spectral bands of visible and near infrared spectral region were obtained for vegetation analysis. LIDAR point cloud was used to estimate vegetation structure differences and visual high resolution images were acquired for validation purposes. During summer period two peatland habitat and restoration specialists collected field data in project areas of GEST vegetation classes as a refence data for further remote sensing data analysis. Final process was to reclassify GEST maps as CO_2, CH_4 and global warming potential (GWP) maps according to previous GEST analysis that defined GHG values for each GEST class.

As a result of the remote sensing data analysis, the produced GEST classification of the peatland areas approved to be detailed and presented accurate peatland vegetation types. Created CO_2, CH_4 and GWP maps presented complexity and diversity of peatland GHG emission process among various peatland areas and inside of large areas as Sudas-Zviedru Mire or Madiešēni Mire in Augstroze Nature Reserve. In total, ten GEST-types were identified in the study sites. Dominating GEST-type in both studied raised bogs is *Wet peat moss lawn* with patches of *Oligotrophic peatland – Moderately moist Forest and shrubberies* covering the degraded area along drainage ditches. The inter-dune mire relief is suitable for *Wet tall sedges reeds* and *Very moist Meadows, forbs and small sedges reeds*, whereas *Wet calcareous Meadows, forbs, …* have developed in Engure fens. Different forest GEST-types are common on bog islands and on margins of inter-dune mires. Spatial structure of GEST-types is partly consistent with mapped habitats in studied peatlands, however minor differences indicating to water level and vegetation structure properties were found.

During the study developed GHG emission assessment method of combination between GEST and remote sensing data analysis demonstrated promising results which can be applied for further GHG emission studies in peatlands especially for complex and large areas with high peatland habitat diversity and mixture. The method is appropriate for GHG emission modelling and assessment before and after peatland restoration actions. Advantage of the method is visually attractive GHG emission maps that can help in communication with various audience to raise awareness and increase understanding and knowledge of peatland importance on global climate stability.

The study is part of a project "Attālajā izpētē balstītas SEG monitoringa metodikas izstrāde purviem" (No. 1-08 /146/ 2018) that is supported by Latvian Environmental Protection Fund.

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MAPPING OF ECOSYSTEMS AND THEIR SERVICES – LATVIAN COASTAL ECOSYSTEMS CASE STUDY

Inga Hoņavko
Nature Conservation Agency
LIFE EcosystemServices (LIFE13 ENV/LV/000839) Project manager
inga.honavko@daba.gov.lv

Keywords - ecosystem services, mapping and assessment of ecosystems, coastal ecosystems.

Introduction

In the context of Latvia the concept of ecosystems and their services and researches of ecosystem services (ES) are relatively new. Assessment of ES in Latvia was started within several projects and one of them is LIFE EcosystemServices within which Latvian coastal ecosystem and their services assessment methodology has been elaborated and verified in two pilot implementation areas – coastal areas Jaunķemeri (90.85 ha) and Saulkrasti (132.86 ha).

The aim of the paper

is to present the approach applied to mapping ecosystems and their services in Latvia coastal areas – two pilot implementation areas.

Methods

The paper focus on verified mapping methodology appropriate for specific Latvia condition and introducing with developed indicators for ecosystem services (ES) biophysical assessment. The ecosystem services identification and classification was based on the Common International Classification of Ecosystem Services (CICES). Expert method for identifying and biophysical assessment appropriate ES was used combine with available data. Experts of different fields were involved and worked on more than 20 indicators. One or more criteria were used describing each ecosystem service indicator. To generate an aggregated assessment of ES – an index was calculated for each spatial unit as a sum of the average assessment values of each ES category (provision, regulation and cultural).

Results

Finally overall matrix for multi-layered ES assessment and multi-layer map for each pilot implementation area were developed. The assessment values are used to create a map for each ES, to incorporate in ES economic valuation and for the project impact on ES supply in pilot areas monitoring.

Conclusions

According to the mapping and assessment of ecosystem services the forest ecosystem has been assessed as most valuable, followed by sandy beach, dunes and river ecosystems.

NATURE CENSUS IN LATVIA

Irisa Mukāne, Gita Strode, Anita Namateva
Nature Census project, Nature Conservation Agency
skaitamdabu@daba.gov.lv

Since November 2016, the EU Cohesion Fund co-financed project 'Preconditions for better biodiversity preservation and ecosystem protection in Latvia', or the 'Nature Census', is being implemented in Latvia. The aim of this project is to establish preconditions for the preservation of biological diversity and protection of ecosystems by carrying out analysis of acquired basic information, as well as to develop twenty specially protected nature conservation plans and five specially protected species protection plans. As a result of the project implementation, the data obtained are entered in the nature management system «Ozols» and can then be used in the development of various planning documents, as well as in the processes of environmental impact assessment, territorial planning, etc.

The identification of the distribution and quality of specially protected habitats of European Union importance in Latvia is implemented in the period of three years from 2017 to 2019, determining the area and quality of these habitats. 60 habitat types of EU importance are identified for six habitat groups - grasslands, forests, swamps, coastal areas and sand dunes, rivers, lakes, exposed rock formations. The total area surveyed by experts is less than 2 million hectares, which includes land of the state and municipalities and private owners.

To facilitate the transparency of mapping works, the whole territory of Latvia is divided into a grid of 12.5 km x 12.5 km squares. Mapping is carried out in accordance with the "Methodology for the Distribution and Quality Identification and Work Organization of Protected Habitats of EU Importance" of the Ministry of Environmental Protection and Regional Development and approved by the Ministry of Agriculture. Field work is carried out by experts from April to October, while digitalisation, verification, refinement and data review for fieldwork in the coming seasons is ongoing. Land owners (legal possessors) whose property is being surveyed are informed about habitat identification.

As a rule, bogs develop in areas with persistent or prolonged humidity, as well as in areas where groundwater is close to the surface of the soil or is discharged on the surface. In such areas, the following bog habitats are found: Active raised bogs (7110 *), Degraded raised bogs still capable of natural regeneration (7120), Transition mires and quaking bogs (7140), Depressions on peat substrates of the *Rhynchosporion* (7150), Alkaline fens (7230), Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae* (7210 *), Petrifying springs with tufa formations (cratoneeurion) (7220 *), Fennoscandian mineral-rich springs and springfens (7160 *).

When analysing the areas of mapped bogs, the most frequently found habitat of EU importance was active raised bogs.

Preliminary data from all EU bog habitat surveys show that 40% of habitats are in good quality, 40% medium, 7% of habitats are in excellent quality, while 13% are in low quality.

A more comprehensive analysis of the distribution and quality of habitats of EU importance will be carried out in 2021, when the data received will be checked, compiled and digitized. However, at present, based on preliminary data, a report has been prepared for the European Commission on the assessment of habitats of EU importance in the country. According to this report, one can conclude:

1. Areas of habitat 7110 * and 7120 in the country after the identification of habitats of EU importance are likely to be smaller than estimated to date. The 7110 * area reduction is mainly due to more accurate data. The reduction of habitat 7120 can be explained by clarification of interpretation, incl. mapping that now excludes degraded bog areas where no natural regeneration is possible - i.e. all abandoned peatland fields that need to be recultivated and which are currently not significant from the economic or biodiversity point of view.
2. The area of alkaline fens in the country can actually be larger than estimated so far, but the quality of these habitats is also on the decline.
3. Natural dystrophic lakes and ponds (3160) is most directly associated with active raised bogs and their conservation. In the future, their conservation status will depend on whether and how much it is planned to develop bogs so far little affected by human activity.

PEATLAND RESTORATION FOR CARBON SEQUESTRATION AND CLIMATE CHANGE MITIGATION IN THREE LATVIAN PEATLANDS – LIFE PROJECT "PEAT RESTORE"

Māra Pakalne, Līga Strazdiņa, Agnese Priede, Krišjānis Libauers
University of Latvia
mara.pakalne@lu.lv

Keywords: greenhouse gas emissions, degraded peatlands, rewetting.

Introduction

During the previous decades the Latvian peatlands are influenced by drainage and peat harvesting. To restore the drained and degraded peatlands and to diminish the greenhouse gas (GHG) emissions, within the LIFE Peat Restore project (LIFE15 CCM/DE/000138) re-establishment of natural carbon sink function of peatlands is planned in three sites in Latvia. Additionally, GHG emissions are being measured before and after restoration to demonstrate the role of peatland restoration in mitigation of climate change. Since the LIFE Peat Restore project is international (involves partners from Latvia, Estonia, Lithuania, Germany, and Poland), the results can be compared at international level.

The aim of the LIFE Peat Restore project is improving the functioning of mire ecosystems, including carbon sequestration capability.

Materials and methods

Restoration of peatland ecosystems will be performed in three sites: Lake Engure Nature Park, Baltezers Mire Nature Reserve, and Augstroze Nature Reserve. In all sites, drainage ditches will be blocked. In Engure site, overgrowing of an alkaline fen will be prevented by cutting shrubs and trees in 20 ha area. On the same time, fluctuations of water table will be reduced by blocking of two ditches using plastic piling. To eliminate the drainage impact in transition mire in Baltezers Mire, eight peat dams will be built on ditches in the mire periphery. Since the tree cover in the restoration area has established mostly due to drainage impact and considerably contributes to evapotranspiration, it is planned to cut the trees and shrubs in 34 ha area. In the restoration area of degraded raised bog habitat in Madiešēnu Mire, 23 peat dams will be built on drainage ditches in total length of 6.2 km.

To evaluate the efficiency of restoration actions, vegetation and water table monitoring was established in summer 2018 in all project areas in Latvia. Vegetation in each site is monitored in 3–4 square-shaped sample plots of size 100 m^2 (10 x 10 m) located close to transects of water table monitoring wells (piezometers). For detailed description of vegetation, the large plots are subdivided into small units, 1 x 1 m internal subplots, in total nine within each large square. To measure the groundwater fluctuations, in total 29 water table piezometers were established at different distances from the ditches where building of dams is planned. Each piezometer is equipped with automatic data logger that measure the groundwater table each hour, i.e. 24 times per day.

LIFE Peat Restore is testing an innovative indirect method to assess GHG emissions in all project sites. Based on the recently developed GEST (*Greenhouse gas Emission Sites Types*) approach (Cowenberg, 2012; Günther et al., 2018), GHG are quantified before, during and after restoration. This approach allows rapid and cheap assessment of GHG emissions (including Global Warming Potential) on basis of vegetation maps. Vegetation forms, integrating flora as well as environmental parameters (soil moisture, trophic level, etc.), can be categorised as particular GEST-types. It is expected that the data provided by monitoring will demonstrate the potential of peatland restoration for climate change mitigation.

Furthermore, GHG samples will be collected for laboratory analysis using closed chambers in all project sites, thus supplementing the results from the GEST approach. Additionally, there are three data loggers, one in each project site, that measure air temperature, air moisture and light intensity. Linking the relevant data on hydrology, peat depth, pH, trophic level and land use will enable the project experts to develop and improve the present GEST catalogue and fill existing gaps.

Results

Detailed description of necessary and planned actions to restore peatlands is given in three plans prepared by the LIFE Peat Restore project: Mire Restoration Plan for Alkaline Fens in Lake Engure Nature Park, Management Plan of the Baltezers Mire Nature Reserve, and Management Plan of Augstroze Nature Reserve. According to these plans and technical designs, dam building in project sites will be performed in 2019 and 2020.

All three Project restoration areas have distinct vegetation, and are characteristic with different hydrological regime, peat properties, land use history and impacts. Engure site represents alkaline fen communities, Baltezers Mire – transition mire communities with elements of alkaline fens and raised bogs, and Augstroze site – typical raised bog communities at different degrees of degradation. Monitoring plots of Engure and Baltezers show similarities in species composition regarding the soil/peat pH parameters, whereas Engure and Augstroze share similar light conditions opposed to half-shaded and shaded plots in Baltezers. In total, 127 species were found in all 90 subplots. The species richness was significantly higher in Baltezers than at both other sites.

Water table in all project sites during first year (2018) was low, mostly due to low amount of precipitation. It was the highest in spring, but dropped down during the vegetation season. Water table fluctuations in Engure site are quicker than in raised bog and transition mire with larger peat deposits. In all sites, the largest amplitude in water table fluctuations was observed near the drainage ditches.

GEST mapping, first time used in Latvia, showed wide range of GEST-types. In total 14 GEST-types were identified (Table 1). Similar to large EU habitat diversity, the highest number of GEST-types was found in Augstroze Nature Reserve (11 types). In this site, the largest area is covered by Wet peat moss lawn (analogue to habitat 7110* Active raised bogs) followed by Wet peat moss hollows resp. flooded peat moss lawn (= 7140 Transition mires and quaking bogs). Eight GEST-types were found in Baltezers Mire Nature Reserve. Dominant types are Oligotrophic moist forests and shrubberies (= 9010* Western Taïga), Wet tall reeds (represent water vegetation of the Lake Baltezers), and Wet meadows and forbs (= 7140 Transition mires and quaking bogs). Two GEST-types are common in restoration area of Engure site – Wet calcareous meadows, forbs,... (include two habitat types of EU importance: 7230 Alkaline fens, and 7210* Calcareous fens with *Cladium mariscus...*) and Wet tall sedges reeds. Six GEST-types might be directly affected by restoration actions within the project. Comparing the baseline scenario with post-restoration scenario (after 50 years), the total predicted amount of GHG emissions in Baltezers and Madiešēnu Mires (Augstroze) is significantly smaller after restoration, thus reaching the project goals. In Engure site, in short term no significant changes in GHG emissions are expected.

Table 1. Classified GEST-types in project sites with their corresponding habitats and protected habitats of EU importance (Annex I of the EU Habitats Directive).

GEST-type	Corresponding EU habitat type	Project site
Open peatland areas (unused)		
Moderately moist (forb) meadows	6270* Fennoscandian lowland species-rich dry to mesic grasslands, 6510 Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis)	Augstroze
Very moist meadows, forbs and small sedges reeds	7140 Transition mires and quaking bogs; fens	Augstroze
Wet meadows and forbs	7140 Transition mires and quaking bogs	Baltezers
Wet calcareous meadows, forbs,...	7230 Alkaline fens, 7210* Calcareous fens with Cladium mariscus and species of the Caricion davallianae	Engure*
Wet tall sedges reeds	-	Engure*
Wet tall reeds	3130 Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoeto-Nanojuncetea	Baltezers, Augstroze
Wet peat moss lawn	7110* Active raised bogs	Augstroze
Wet peat moss hollows resp. flooded peat moss lawn	7140 Transition mires and quaking bogs	Baltezers, Augstroze

Oligotrophic peatlands		
Dry forest and shrubberies	9050 Fennoscandian herb-rich forests with Picea abies	Baltezers, Augstroze
Moderately moist forests and shrubberies	91D0* Bog woodland	Baltezers, Augstroze
Moist forests and shrubberies	9010* Western Taïga	Baltezers, Augstroze
Mesotrophic and eutrophic peatlands		
Moderately moist forests and shrubberies	9020* Fennoscandian hemiboreal natural old broad-leaved deciduous forests (Quercus, Tilia, Acer, Fraxinus or Ulmus) rich in epiphytes, 9080* Fennoscandian deciduous swamp woods, 9160 Sub-Atlantic and medio-European oak or oak-hornbeam forests of the Carpinion betuli	Baltezers, Augstroze
Moist forests and shrubberies	91E0* Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)	Baltezers, Augstroze
Very moist forests and shrubberies	9080* Fennoscandian deciduous swamp woods	Augstroze

* For Engure site, only project restoration area (fens) was analyzed.

Conclusions

Restoration activities in project sites in Latvia will significantly eliminate GHG emissions and improve the mire ecosystem functions including carbon sequestration capability. According to GEST estimation, successful restoration can reduce emissions by more than one half in Madiešēnu Mire in Augstroze (raised bog). Additionally, restoration will improve the quality of protected habitats of EU importance and environmental conditions for many threatened species. In Engure site, though the estimated GHG emissions might remain similar to the baseline scenario, the drainage effects will be eliminated, thus ensuring the peat formation and carbon sequestration in the future.

GHG measurements in peatland rewetting projects, including LIFE Peat Restore, contribute to understanding the importance of hydrological restoration. Though it is well known that blocking the drainage ditches and removal of trees contribute to reduction of GHG emissions, still direct measurements are necessary for quantitative evaluation of rewetting actions. Therefore, the results of LIFE Peat Restore will improve the understanding of GHG emissions in peatlands of northern and north-eastern European countries.

However, direct GHG measurements are not always possible due to limited funding. Hereby, theoretical emission assessment methods are useful. Testing GEST approach in five countries within LIFE Peat Restore project will allow assessment of the suitability and further use of this approach in similar rewetting projects.

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RESTORATION EXPERIMENT OF SPHAGNUM MAGELLANICUM IN THE PYRENEAN MIRES

Jordina Gili, Aaron Pérez Haase, Jaume Espuny
University of Barcelona, Faculty of Biology, Diagonal 643, Barcelona, Spain

Introduction

Mires landscapes have a high conservation interest, hold various Habitats of Community Interest (HCI) and occur in temperate and boreal regions, however, in Catalonia (Spain) are exclusively in the Pyrenees, linked to places where the topography or circulation of water is favorable (Pérez-Haase & Ninot, 2004). In the case of the Pyrenees, these habitats are often altered by flocks. On the other hand, they have also been locally affected by the construction of hydroelectric dams in their basin that have altered the natural hydrological cycle (Ventura et al., 2014). Given the degradation of the mires, the restoration of these systems has become an important issue over the last decades. The restoration of mires seeks to restore a vegetation cover and hydrological conditions dominated by peat mosses (*Sphagnum* spp.), which play an important role in this process.

The aim of the study is to identify in which experimental conditions a greater response is obtained in the survival and growth of *Sphagnum magellanicum,* a vulnerable species (VU) according to the Red List of threatened bryophytes in Spain and included in the Catalog of threatened flora of Catalonia and to establish the bases for the restoration of their populations.

Materials and methods

Based on the combination of different flood situations (three different water levels) and the interaction of species (intraspecific and interspecific), it is desired to identify under which experimental conditions a greater response is obtained in the survival and growth of *S. magellanicum*. In order to carry out the objective of this work and to study interspecific interaction we selected two *Sphagnum* species that often share part of their habitat with *S. magellanicum*: *S. teres* and *S. capillifolium.*

In order to carry out this experiment and to carry out the replication a total of 675 individuals distributed in 225 outbreaks of *S. capillifolium,* 225 of *S. magellanicum* and 225 of *S. teres* were randomly selected from different systems of mires located around Trescuro (Peguera Valley - Espot).

To create situations of interspecific interaction three individuals of each species were planted in an interspersed manner in the same container, obtaining a total of three containers; one for each combination of species - *S. capillifolium* with *S. teres*, *S. capillifolium* with *S. magellanicum* and *S. magellanicum* with *S. teres*. In order to be able to differentiate the effect of the density of individuals with respect to the effect of the interaction between different species we created the intraspecific interaction treatment, where six individuals of the same species were planted, obtaining three more containers (one for species). Finally, in the control situations three individuals of the same species were planted, also obtaining three containers more. In total, nine combinations of containers for each block was created. Peat as a growth substrate was used, since in natural conditions the *Sphagnum* species develop on this substrate. Regarding the depth of the water, three levels with respect to the surface of the container were established: dry level (-5 cm), level at the height of the container (0 cm), and a flood situation (+3 cm). So, in order to control the depth of the water, we used a total of 15 trays, that is, five replicas of each situation of interaction for each water level. Each tray contained the 9 containers with the different combinations of species interaction.

The distribution of the containers in the trays was random, and every month a swap of containers was made, also random. Once a week the random exchange of the trays was made, to which each exchange we changed orientation. Finally, maintenance of the water levels of the experiment in order to maintain the water level initially established was carried out.

The water to create the different flood situations tried to simulate the concentrations of elements contained in the precipitation water of the Pyrenees (Camarero & Catalan, 1996). The same water was used to water the tubes by means of a spray gun.

The experiment was conducted in chambers 16 and 17 of the Experimental Fields of the Faculty of Biology of the University of Barcelona. We established conditions of 22ºC for 16h and 15ºC at 8h rest of darkness. These conditions correspond to summer temperatures favorable for the growth of *Sphagnum* species. The duration of the experiment was 119 days, from the end of December 2017 until the end of April 2018.

Results

In order to analyze the data, three response variables that could explain the growth of *Sphagnum magellanicum* were selected: (i) Final length; (ii) Final dry weight and (iii) Number of final total shoots. All variables were measured at the individual level and were treated statistically with the mixed linear models (Linear Mixed-Effects Models) through program R.

i. Of the three levels of water depth, the growth in length of Sphagnum magellanicum is significantly higher in the conditions of level 0 (75.53 ± 7.20 mm) compared to treatment with a higher water level (53, 31 ± 17.41 mm) and treatment with a lower water level (43.47 ± 8.31 mm). The differences between the three treatments are statistically significant. Regarding the interaction, the growth in length of Sphagnum magellanicum has not been significantly affected in any treatment.
ii. In this case, the growth of Sphagnum magellanicum in dry weight is significantly higher at level 0 (0.02 ± 0.01 g) compared to the lower water level (0.01 ± 0.00 g) and level Higher water (0.01 ± 0.00 g). Regarding the interaction, the growth of Sphagnum magellanicum in dry weight is not significantly affected in any case.
iii. Regarding the level of depth of the water, Sphagnum magellanicum makes more shoots in the highest water level (2.82 ± 2.20) and in level 0 (2.36 ± 1.33) respect of the lowest water level (1.57 ± 0.98) with marginally significant differences. The differences in the total number of outbreaks between levels 0 and 3 are not significant. Regarding the interaction, Sphagnum magelllanicum did not significantly increase any outbreaks in any treatment.

Conclusions

Significant effects were observed on the growth of *Sphagnum magellanicum* with regard to the water level, although interaction between species did not cause growth differences in the study cases. We conclude that the growth of *Sphagnum magellanicum* is significantly favored by the intermediate water level. However, it has shown a wide ecological niche through response mechanisms that have facilitated its adaptation both in flooded and dry water levels showing a very high survival in all the proposed treatments.

Looking to the restoration of *Sphagnum magellanicum* we propose to reinforce their populations in hummocks that are nourished by the precipitation of water. In addition, since it has not responded negatively to any situation of interaction, we propose to reinforce their populations through their incorporation in existing carpets of *Sphagnum teres* and in existing hummocks of *Sphagnum capillifolium.*

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SPONTANEOUS REVEGETATION IN HARVESTED PEATLANDS IN LATVIA PROVIDES INDICATORS FOR ASSESSING SUCCESS OF REHABILITATION

Agnese Priede, Botanical Garden of the University of Latvia, agnese.priede@lu.lv
Anna Mežaka, Institute of Life Sciences and Technologies, Daugavpils University, anna.mezaka@biology.lv

Keywords: after-use of harvested peatlands, secondary vegetation, rare plant species, vegetation recovery.

Introduction

In Latvia, abandoned harvested peatlands cover ~18 thousand hectares (recent results provided by LIFE REstore project[17]). They represent areas that are extracted or partly extracted and abandoned without any rehabilitation measures mostly during the soviet period. These are problematic areas both from biodiversity conservation and landscape perspective, as well as contribute to climate change with large greenhouse gas emissions.

In practise, spontaneous recovery of *any* vegetation type after abandonment is sometimes misinterpreted as "renaturalisation", a term that covers solely re-creation of mire conditions in the Latvian national legislation. On the other hand, our own observations and some studies suggest that such areas can be valuable from biodiversity point of view, though rarely, e.g. serve as important bird areas or habitats for rare plant species and communities if the drainage systems do no function any longer. Sometimes lack of

17 Project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103).

knowledge and experience in assessing the actual condition of such areas in terms of biodiversity and ecosystem functioning might lead to wrong decisions on after-use, e.g. a self-regenerating alkaline fen, a rare habitat in Latvia, might be considered as area for afforestation.

The aim of this study was to explore the actual condition of these degraded peatland areas from the biodiversity perspective and their capability of recovery as functioning wetland ecosystems. We attempted to identify simple indicators that would help land managers to distinguish between well-recovering peatland and degraded peatland in terms of "renaturalisation" in Latvia. This is related with identifying the major drivers that allow recovery of mire ecosystem successful and those which make it impossible. Here, we present the major factors that differentiate the development of either one, or another mire type in harvested peatlands.

Material and methods

The field work was done in 11 harvested peatlands (milling and peat cutting fields, peat quarries were excluded) within framework of PuREST project (No. 1DP/1.1.1.2.0/13/APIA/VIAA/044) in 2014–2015. Peatlands represented different types of remaining peat in the upper layer, different time period since abandonment and different area. However, all of them were abandoned, and peat extraction was ceased for at least 10 years (the age varied from 10 to 60 years).

In each site, vegetation in 30–60 (depending on the peatland area) 25 m^2 (5 x 5 m) plots was sampled: all taxa of vascular plants, bryophytes and lichens were identified and their cover (%) evaluated. The sample plots were located in transects crossing the peat field. In only in site the number of sample plots was smaller (five plots). In total 365 sample plots were described. In each plot, the following environmental variables were recorded: age (time since abandonment), moisture, decomposition of upper peat layer, peat depth, micro-relief (all four variables were estimated in relative units, classes), litter (%), and pH and EC of peat water (measured using portable pH/EC meters).

The data were analysed using Canonical Correspondence Analysis (CCA), Non-metric Multidimentional Scaling (NMDS) with Jaccard method.

Results

The vegetation types in the study areas were differentiated primarily by pH (related with peat type) and moisture. Thus, the plant communities (and consequently also site conditions) could be differentiated by dominant residual peat type – either bog, or fen peat, and then classified according to the species composition and relevant environmental variables. The species richness was greater and the number of characteristic species of natural mire habitats was higher in harvested peatlands that were abandoned several decades ago.

Our results suggest that some species can be used as simple indicators of degradation and success of rehabilitation of harvested peatlands. However, always the background information (especially hydrological conditions), the abundance of the particular indicator species and the combination with other species must be taken into account.

The vegetation in post-harvested peatlands with remaining bog peat is less variable than in fen sites, and the sites with remaining bog peat are more similar to each other than those with fen peat. Basically, the dry peat fields with functioning drainage systems lack species characteristic for intact raised bogs (e.g. *Sphagnum* spp.). The areas are dominated by few species of dry conditions and species which tolerate large water table fluctuations, e.g. *Eriophorum vaginatum*, *Calluna vulgaris* and some other dwarf shrubs, few moss and lichen species indicating dry conditions. This species-poor stage can last for several decades. By time, within few decades, these areas tend to overgrow with secondary forest vegetation, whereas the diversity of ground vegetation remains low, and the peat formation process does not recover because of too dry conditions. This is one of the "bad scenarios" which does not lead to recovery of mire ecosystem and its functions, and represents very low species diversity of decades. For identification of too dry conditions of peat fields with remaining bog peat the following species can be used: *Eriophorum vaginatum* (in combination with *Calluna vulgaris*, both dominating), *Pleurozium schreberi*, *Dicranum polysetum*, *Campylopus introflexus*, *Cladonia* spp.

Wet peat fields with residual bog peat may have slightly more variable vegetation which is defined by wetness, most probably also by fluctuations of water table, and physical and chemical properties of water. Successful recovery of mire vegetation is indicated by presence of bog, transition mire and poor fen plants, e.g. *Rhynchospora alba*, *Oxycoccus palustris*, *Drosera* spp., *Carex rostrata*, *Eriophorum polystachion.* also the key species – *Sphagnum* spp.

The character and vegetation of secondary fens which develop after peat harvesting differed from site to site, only in few sites similarities were found. Therefore, generalisation of such areas is problematic. The variation of vegetation in dry peat fields with residual fen peat was low, the sites were sparsely vegetated with few grass species (most commonly, *Agrostis canina*) and few moss and lichen species including the invasive *Campylopus introflexus* which may form thick "blankets" outcompeting the native species. Slightly wetter sites may overgrow with *Molinia caerulea* accompanied by few other species. By time, the dry peat fields transform into forest with species-poor vegetation. Secondary fen communities in peat fields with high water table which were found in more than one site were small-sedge communities with *Carex flava* group, *Trichophorum alpinum*, *Juncus articulatus*, *Epipactis palustris*, *Schoenus ferrugineus*, etc. and brown mosses (predomiantly *Campylium stellatum*, *Dreponocladus* spp., *Scorpidium scorpioides*, *Fissidens adianthoides*), and *Cladium mariscus* stands with some brown moss species. Other vegetation types were represented in only one site which highlights the importance of local abiotic conditions and distinct surrounding vegetation. All secondary plant communities recorded on wet peat fields with residual fen peat are considered rare and valuable in Latvia.

We found also some rare, threatened species included in the national protected species lists (e.g. *Schoenus ferrugineus*, *Cladium mariscus*, *Primula farinosa*, *Pinguicula vulgaris*, *Taraxacum palustre*, *Myrica gale*, *Lycopodiella inundata*), as well as *Liparis loeselii*, listed in the Annex I of the EU Habitats Directive. Though presence of protected species cannot be unambiguously interpreted as "success", as some of them indicate dry conditions, i.e. functioning drainage systems (e.g. *Lycopodium* spp., *Huperzia selago*, *Carex ornithopoda*), it suggests that harvested peatlands can become valuable habitats for threatened species if the areas are rewetted and properly managed.

Conclusions

- The results of our study show that abandoned harvested peatlands can be both degraded and valuable from biodiversity point of view. High water table without large fluctuations is the basic requirement for mire vegetation development, i.e. peatland function recovery.
- The species indicators suggested by this study can be used also by land managers in simple field assessments to understand the success of failure of post-harvesting rehabilitation measures. Many of them are excellent indicators that characterise the environmental conditions, both degradation and recovery of mire.
- Rewetted post-harvested peatlands can be important refuges for rare plant species, which can be both remains of the pristine mires or established in the new environment. However, it is important that these sites are rewetted to be important for biodiversity.
- Rehabilitation of harvested peatlands is essential in conservation of rare mire habitats, especially alkaline fens which are highly threatened and fragmented in Latvia. This study suggests that re-creation of rare, valuable mire habitats in harvested peatlands is in some cases possible, though time-consuming process.

THE IMPORTANCE OF GEOLOGICAL STUDIES FOR THE ASSESSMENT OF DEGRADED PEATLANDS

[1, 2]Laimdota Kalniņa, [1,2]Ingrīda Krīgere, [2]Jānis Dreimanis, [2,3]Agnese Rudusāne, [2]Līga Paparde, [2]Reinis Bitenieks

[1] LIFE REstore, Latvian Peat Association
[2]Faculty of Geography and Earth Sciences University of Latvia
[3] LIFE REstore, Nature Conservation Agency of Latvia
Laimdota.Kalnina@lu.lv

The areas where peat has accumulated or is still accumulating cover more than 10% of Latvia's territory. Although part of peatlands is overgrown with forests, or they are drained for agricultural purposes or used for peat extraction and these areas became degraded. Degraded peatlands are areas that have lost ecosystems functions and peat formation possibility as a result of adverse effects.

Over the last hundred years, the development of many mires has been halted by mire drainage (15% for agricultural use and 3.9% for peat extraction), and by their overgrowth with forest, both naturally and in result of human activity. Peatland areas degraded by drainage were the research objects of project "Sustainable and responsible management and re-use of degraded peatlands in Latvia" (LIFE REstore, LIFE14 CCM/LV/001103). In these peatlands it was necessary to determine their geological structure, peat parameters, properties, which is very important to choose the most appropriate complex of management measures for the reasonable use of land resources and for climate change mitigation.

Degraded peatlands have been studied both by field and laboratory methods. Defined 78 peatlands were studied within LIFE Project include both chamber and field research methods, including geological coring and sampling. Pre- and post-field work information is compiled and obtained results are collected and analysed. Peat monoliths obtained in boreholes were studied in field, but 5 peatlands: Lauga Mire, Lielsala Mire, Kaigu Mire, Drabiņu Mire and Ķemeri Mire were additionally investigated in research laboratories of University of Latvia. Analysis included: loss-on-ignition analysis to determine the content of organic matter and ash; analysis of peat decomposition degree and botanical composition; peat pH values; peat density.

As a result of the peatland inventory in the project, it was found that among all the degraded peatlands surveyed in the upper layer is dominated by raised bog peat - 37 peatlands, slightly less degraded areas with fen type peat in the top layer - 29 peatlands, and only one case with peat bog peat transition, but in 7 of the sites surveyed, peat has been removed to mineral deposits (LIFE Restore, 2018).

The study results show that peat properties in residual peat layers are changed. Mainly it is related to pH value, increase of peat density, changes in peat composition, including fluctuations in amount of mineral substances which can be explained by peat mineralization due to mire hydrological regime changes. In some cases, an increase of peat density was observed in upper part of the sediment section where peat was more dry and compacted. Often, pH values in upper peat layer of degraded peatlands do not correspond to pH values of the particular peat type, which indicates a change in environmental conditions due to various influences. Changes in mineral content and carbonate content indicate on changes in sediment accumulation environment – on influence of groundwater which likely introduced carbonates and mineral substances into peat layers.

In areas degraded by peat extraction, where residual peat layer is several meters thick, changes in peat composition can be explained mainly by natural processes. Higher proportion of mineral substances in lower parts of mire sections is determined by the fact that peat has accumulated directly on mineral ground in peatland bottom, and it is influenced by minerogenic sediments and by groundwater flow.

Peat decomposition degree in degraded peatlands in general are similar, and usually vary between 15% and 35%, however, the peat formed directly on the mineral deposits can has higher decomposition reaching 40 to 45%. The upper pest layer can be composed by low or medium decomposed peat. In some cases, changes of this indicator are associated with erosion processes, especially on the top of peat section, where peat is mineralised and dry.

The thickness of the layer thickness in different degraded peatlands changes from zero to those areas where peat was not found at all, up to 4.9 m in Ozolmuižas-Bambišķi Bog in the Latgale Highlands and 5.5 m in Robežnieku-Purmaļi Mire and Zaķu Bog in North Vidzeme According to the research carried out within the LIFE Restore project, information the average thickness of the peat layer, depending on the peat type, is as follows: for raised bog type peatlands the average peat layer thickness is 2.5 m and for fen type peatlands - 1.4 m. The thickness of the peat layer found in the only transitional peatland is 3.23 m. In peatlands of different peat types, the average peat layer thickness is 1.9 m. In order to ensure the rational use of peat resources, peat extraction is the best way to further utilize degraded peatlands containing peat for industrial production.

At the base of the studied 78 peatlands, the results show that sapropel has been found only on 7 sites under peat bed, which can be explained by the fact that peat extraction most often started sequentially from the edge of the peatland and thus, if the whole field is not extracted and the degraded peat fields are located in the periphery of the bog where peat formation was due to paludification processes on mineral deposit. Silt or clay has been found most frequently below the peat layers in the bog suggesting that these sediments have formed in the aquatic environment, as it has been for some time before the formation of the peatland, which has been subject to change due to climatic and geological conditions. At the bottom of the fen type peatlands, sand has been found only in 4 cases, but clay sediments - clay, till and clayey till have been found only in 7 peatland areas, mainly in highlands.

All geological information about the degraded peatland, properties of the remaining peat layer is important to assess what type of recultivation is most appropriate for the area. However the studied degraded peatlands in detail in the frame of the project obtaining information about their condition, peat thickness, peat type, pH and other properties are informative. During the inventory of degraded peatlands they were not investigated according to the procedure established by the Cabinet of Ministers Regulation No.570 "Mining Procedures". This means that in the future, prior to the selection and implementation of the degraded peatland recultivation measures the necessary additional information should be obtained through detailed site research.

ECOSYSTEMS SERVICES ECONOMIC VALUATION: CASE STUDY IN LATVIA

Dr. paed. Aija Persevica, Dr. oec. Elina Konstantinova, Dr. oec. Liga Brunina
Association "Baltic Coasts"

aija.persevica@baltijaskrasti.lv, elina.konstantinova@baltijaskrasti.lv, liga.brunina@baltijaskrasti

Keywords – ecosystem services, ecosystem economic valuation.

Introduction - Ecosystem services (ES) are the benefits that people obtain from using ecosystems and can be divided into the following three categories: provisioning, regulating and supporting and cultural services. Basing on economic valuation of ecosystem services, it is possible to compare different territories and different management scenarios. A strategical importance of ecosystem services is set by EU Biodiversity Strategy, which put ecosystem services firmly on the EU policy agenda.

The aim of the research is to present and discuss the model for ecosystem economic valuation for the socio-economic development planning in Latvian coastal areas.

Methods

When assessing the ecosystem services, a concept of economic values has to be taken into account, which involves Total Economic Value (TEV). TEV consists of direct and indirect values, and the non-use values.

To assess the monetary value of the ES, different methods are used: Direct pricing/ Market price method; Production function method; Avoided cost method, Replacement cost method; Contingent valuation method; Travel cost method; Hedonic pricing method; Benefit transfer method; Other methods or their combination.

There is carried out collection of primary data, aggregation and comparative assessment of secondary data by using approbated scientific research methods and ES assessment indicators. The obtained data is adapted to Latvian social-economic situation by using correction factors. Depending on ES category there were used following assessment methods:

- for assessment of provisioning services – direct market pricing method;
- for assessment of regulating services – benefit transfer method and direct market pricing method;
- for assessment of cultural services - benefit transfer method and travel cost method.

The study was based on the data of Baltic Sea coastal *Saulkrasti* and *Jaunkemeri* pilot areas in Latvia using standardized assessment, which provides different ecosystem services indicators' units to transform into one monetary unit of measurement, such as EUR/ha per year, which makes it possible to compare different services.

The two pilot areas in the coastal zone - *Jaunkemeri* and *Saulkrasti* - have been selected to test the approach of economic valuation the ES for the Latvian coastal conditions.

Pilot area *Jaunkemeri* is located within the city and is part of Kemeri national park. It includes sandy beach and biologically valuable habitat of EU importance – wooden dunes. The area is not much transformed and relatively poorly visited (90,85 ha).

Pilot area *Saulkrasti* is located in Saulkrasti municipality. It includes sandy beach and biologically valuable habitat of EU importance – wooden dunes and remarkable cultural and nature monument – White Dune. The well-maintained nature object is frequently visited and subjected to excessive anthropogenic pressure and erosion (132,86 ha).

Results

The ES mapping and assessment in *Jaunkemeri* and *Saulkrasti* pilot areas resulted with selected and assessed 23 ES classes based on the Common International Classification of Ecosystem Services (CICES). According to the overall ES assessment the forest ecosystem has been assessed as most valuable, followed by sandy beach, dunes and river ecosystems. The regulating services have the largest monetary value in both territories – *Saulkrasti* and *Jauņķemeri* and it is mainly provided by forest areas.

Conclusions

In the result of ES monetary assessment, the following priorities and recommendations can be outlined

- The largest monetary value of all Ecosystem services for both pilot areas has regulating services and it is mainly provided by forest areas. The forest areas are the most valuable areas from ES monetary assessment perspective. Therefore, the priority should be given to management scenarios and measures which are directed to maintain and protect forest ecosystem
- The second priority from ES monetary assessment perspective is given to cultural services assuming that development of tourism and recreation activities would not create additional anthropogenic load on ecosystems but on the other hand will be directed toward nature education and decrease of negative impacts on ecosystems.
- The lowest priority is for provisioning services considering that both territories are located in coastal areas and there are legal and physical restrictions to obtain these services (for example restriction of tree felling and fishing).

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NOTES