PROCEEDINGS

GREIFSWALD
MIRE
CENTRE

RRR2017

Renewable Resources from Wet and Rewetted Peatlands

September 26th - 28th 2017
Greifswald, Germany

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IMPRINT

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Greifswald, September 2017

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Scope and Aim of the Conference

The use of biomass from wet and rewetted petlands (paludiculture) offers many opportunities to address the increasing and diverse demand for biomass. This kind of biomass can substitute fossil resources as a raw material for industry and energy production, using both traditional and new processing lines and techniques. Changing from drainage based management of peatlands to paludiculture can ensure a balanced provision of several ecosystem services like biomass provision and emissions reduction. The cultivation and exploitation of plant species adapted to wet conditions is the only sustainable land use option for peatlands and can reduce competition between biofuels and food production, while maintaining and restoring many ecosystem services.

This 2nd international conference on the utilisation of wetland plants "Renewable resources from wet and rewetted peatlands" (RRR 2017) in Greifswald gathers wetland and paludiculture expertise from all over the world. Since the 1st conference in Greifswald in 2013 important milestones could be achieved in research projects and practical experience has been gathered worldwide. But still obstacles for implementation and knowledge gaps are obvious, and the opportunities and challenges of paludiculture are reflected in research activities worldwide.

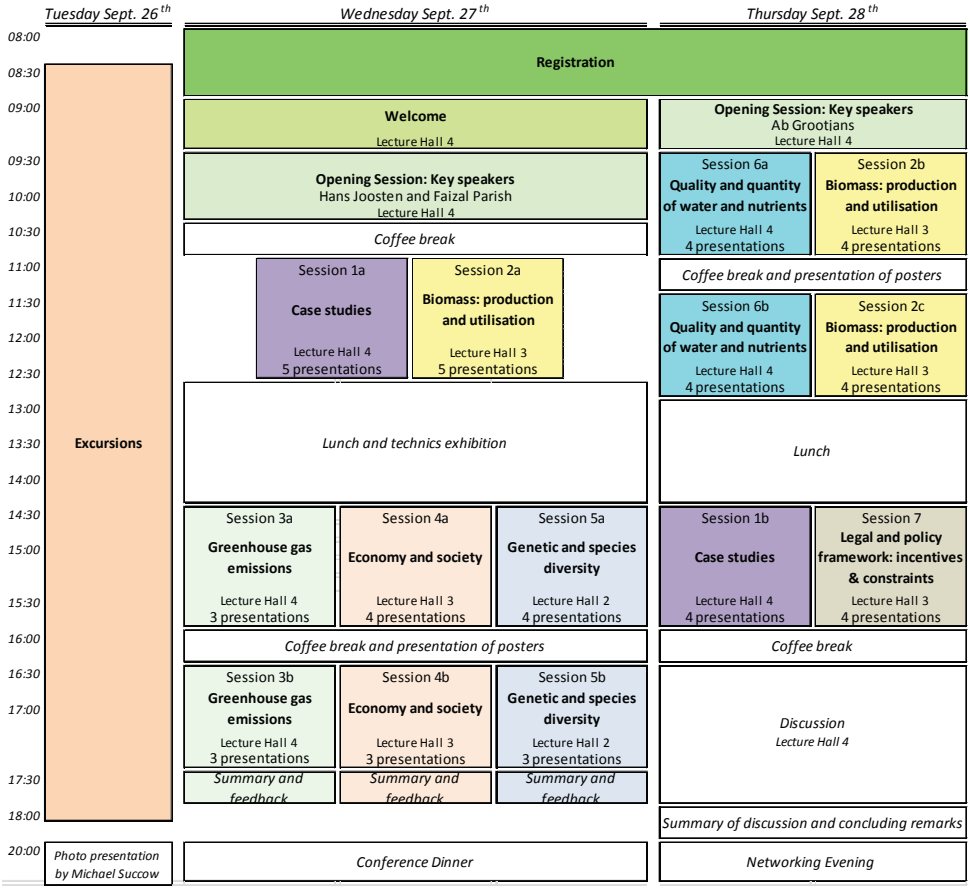
With this conference we want to bring together actors from research, governance, agriculture and nature protection to exchange visions, experiences, ideas and information, to identify research demands and to build networks. We also want to make progress in large-scale implementation of paludiculture. Therefore, this conference addresses not only scientists, but also practitioners, engineers and companies.

Members of the Organising Committee

Susanne Abel, Tobias Dahms, Greta Gaudig, Prof. Dr. Dr. h.c. Hans Joosten, Mira Kohl, Anke Nordt, Dr. Franziska Tanneberger, Sabine Wichmann, Dr. Wendelin Wichtmann, Karin Windloff

Greifswald Mire Centre, Greifswald, Germany

PROGRAMME OVERVIEW



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HOST INSTITUTIONS

Greifswald Mire Centre

The Greifswald Mire Centre (GMC) was founded in 2015 as a cooperation between the University of Greifswald, the Michael Succow Foundation and the Institute of Sustainable Development of Landscapes of the Earth (DUENE e.V.). It consolidates and strengthens already established Greifswald-based institutions in a new centre of excellence.

The GMC is a science-policy-practice interface and an innovator for all peatland related questions – locally and globally. It performs interdisciplinary research, provides policy makers and society with substantiated knowledge and advice, and imparts theoretical and practical knowledge. Currently about 70 peatland experts of various disciplines are concentrated in the GMC.

The GMC coordinates four large peatland databases, among them the „Global Peatland Database“ (the largest database of distribution and status of peatlands worldwide) and the extensive library „Peatland and Nature Conservation International Library“ (PeNCIL).

The GMC’s main topics for the period 2015-2022 are:

- Climate change: Quantification and reduction of greenhouse gas emissions from peatlands and ecosystem-based adaptation,
- Ecosystem services of peatlands: Identification, quantification and monetarisation,
- Biodiversity: Identification, conservation and restoration of peatlands and its habitats worldwide,
- Sustainable use: Development of paludiculture and innovative financing.

University of Greifswald

The University of Greifswald was founded in 1456 and is among the oldest academic institutions in Europe. Over 12,000 students from all over the world study in Greifswald.

The university offers a traditional, wide range of subjects and is structured in five faculties: Theology, Law and Political Sciences, Philosophy, Mathematics and Natural Sciences, and Medicine, being subdivided into several institutes and clinics. Thanks to the excellent scientific work of the university, the city of Greifswald has increasingly gained in charisma and importance on a national as well as on an international level. Ecological research (ecosystem change, response and adaptation) is one of the five research priorities of the university. Research and teaching related to peatlands is mainly located at the Institute of Botany and Landscape Ecology, where Prof. Hans Joosten leads the Department of Peatland Studies and Paleoecology.

The conference is (financially) organised by the University of Greifswald.

HOST INSTITUTIONS

Michael Succow Foundation for the Protection of Nature

The Michael Succow Foundation for the Protection of Nature (German: Michael Succow Stiftung zum Schutz der Natur) was established in 1999 and is one of the oldest foundations for nature conservation in Eastern Germany. It was founded using the money from the Right Livelihood Award, bestowed upon Prof. Dr. Michael Succow in 1997. The foundation is campaigning for sustainable land use and the active conservation of valuable landscapes.

In national and international projects, it contributes to climate protection, the conservation of biodiversity, the creation of wilderness areas and the education and further qualification of actors in nature and environmental conservation. The motto "Preserve and Sustain" is the kernel of the foundation's work, both in the implementation of practical nature protection plans as well as in the development of nature conservation and land use concepts for our and future generations. Protection and sustainable management of wetlands, especially peatlands, is one of the main goals of the foundation.

Institute of Sustainable Development of Landscapes of the Earth (DUENE) e.V.

The scientific non-profit association „Institute of Sustainable Development of Landscapes of the Earth" (German: Institut für Dauerhaft Umweltgerechte Entwicklung von Naturräumen der Erde e.V. - DUENE) was founded 1999 at the Institute of Botany and Landscape Ecology of the University of Greifswald. The main objective of DUENE is the conservation of natural and cultivated landscapes and the support of sustainable development of landscapes. Current interdisciplinary applied research in landscape ecology and economics focuses on sustainable land use. DUENE has a particularly strong background in economics of paludicultures, and in productivity and usability of wetland plants. Other major activities include the restoration of degraded landscapes, payments for ecosystem services schemes and carbon credits, constructed wetlands and nutrient retention, and the protection of threatened species.

CONFERENCE VENUE

Campus Loefflerstraße

The Campus Loefflerstraße is just developing from a Centre of Medicine with several clinical buildings to a new campus of the Faculty of Philosophy. Old buildings are just under reconstruction and prepared for their new utilisation, other buildings were newly constructed and since recently have been in use for regular studies and teaching as well as extraordinary activities like conferences and congresses.

1 Conference building
2 RUMOOREN Art Exhibition
3 Lunch @Mensa am Schießwall
4 Conference Dinner @Theater Cafe
5 Technics exhibition @Market square
6 Main station
7 Meeting point excursion @bus station
8 Paludiculture plants @botanical garden
9 Networking evening @ST. Spiritus

Location

The city of Greifswald, situated in northeastern Germany at the Baltic Sea coast, is a founding member of the Hanseatic League of Towns (1299). It is situated amidst extensive forests, peatlands, lakes, seascapes, and ecological agriculture, including several national parks and biosphere reserves and many large restoration projects.

The old part of town that could be spared from destruction during World War II and was lovingly restored is one of the greatest cultural assets of Greifswald. Its medieval layout, arranged like a chessboard, as well as the picturesque narrow streets are completely preserved. 200 years ago, the old city's skyline had already fascinated its most popular resident, Caspar David Friedrich. The imposing churches of St. Nikolai, St. Marien and St. Jacobi, "Long Nicholas," "Fat Mary" and "Little James," as they are lovingly called by the Greifswald residents, are a reminder of the prosperity of the city in medieval times. The churches are, together with the gable houses out of brick at the east side of the market, Greifswald's contribution to the fascinating world of the Brick Gothic, the European route of which spans from the Danish city of Århus up to the Estonian city of Tartu.

The Market Square with its view of the churches offers the visitor one of the most beautiful northern German market place ensembles. The Pomeranian Regional Museum in Greifswald allows a good exploration of the geological past and 14,000 years history, culture and arts in the region. The museum hosts a high-calibre exhibition, among the exhibits art treasures from the university like the Croy Carpet dating back to the year 1557.

In spite of its more than 750 years old history, Greifswald is a young, lively city: "a university with a city, rather than a city with a university," the residents say. Thanks to the excellent scientific work of the university, founded in 1456, the town of Greifswald has more and more gained in charisma and importance, on a national as well as on an international level.

WELCOME TO GREIFSWALD!

Dear Conference Delegates,

It is a great honor for me to welcome you to the University and Hanseatic Town of Greifswald. I am delighted to see the second international paludiculture conference take place here, in the northeast of Germany.
Greifswald does actually have a long history in peatland research – nearly 200 years ago Adalbert von Chamisso started to look at peat utilisation and peat accumulation in a mire north of Greifswald. Recently there has been a growing research interest in sustainable peatland utilisation for more than 20 years.
In Mecklenburg–Western Pomerania about 12 % of the land surface is covered with peatlands of which the great majority is drained and degraded. Greifswald lies at the river Ryck, a lowland stream with extensive peatlands. The water quality of the river Ryck is in an insufficient ecological condition which could be improved by rewetting adjacent peatlands to reduce nutrient output into the river and the Baltic Sea. I launched the initiative "Clean Ryck" to bring together Greifswald University, Michael Succow Foundation, the City of Greifswald as well as other partners as joined forces looking for answers to improve the water quality of the Ryck. Establishing paludiculture after rewetting could be a great opportunity to intensify practical knowledge transfer and large scale paludiculture research in Greifswald.
Hosting your conference in Greifswald also goes with the city's goal to become a Masterplan Community. We are planning to reduce GHG emission by 95% until 2050, and the utilisation of paludiculture-biomass for local heat supply could be one source of sustainable energy supply.
I wish you a successful, productive and inspiring meeting and hope that you will also find time to explore our town and its beautiful surroundings. Please, feel invited to come back again!
With my best wishes for your stay
in Greifswald

Dr. Stefan Fassbinder
Lord Mayor of the city of Greifswald

Instructions for Participants of the Conference

Instructions for session organisers and chairpersons

Please arrive at the conference rooms at least 15 minutes before the session starts and make contact with your speakers. There will be assistants to help with technical questions. All rooms are equipped with a laser pointer. With so many speakers and another sessions running concurrently we need to adhere strictly to the time schedule and we rely very much on you as chairperson. Please notify the speakers that they have 15 minutes speaking time and 5 minutes for discussion. You are requested to ring a little bell after 15 minutes to allow some discussion.

We kindly ask all chairpersons to summarise the main messages of their sessions for the final statement of the conference. Please write not more than half a page (this can be bullet points, not an Oxford English essay) and give it until 28.09.2017, 14:00 h to the registration desk. Thank you very much for your support!

Instructions for oral presentations

The timing of your presentation is of utmost importance. With so many speakers and another sessions running concurrently, we need to adhere strictly to the time schedule. Please, practice your talk and make sure that it will not overrun your time slot. The length of your talk is limited to 15 minutes with an additional 5 minutes reserved for discussion, which is considered as important as your presentation.

All speakers are requested to be in the room of their session at least 15 minutes before the session starts, to bring your presentation to the technical staff and to contact the session's chairperson. Please note that it will not be possible to connect your own laptop to the projector. We want your presentation in a recordable CD or a memory stick readable by a Windows PC (pdf, ppt or pptx). Please be responsive to the indications on the timing near the end of your talk. Your chairperson will ring a bell after 15 minutes, when you have used all of your time and need to end your talk immediately.

Instructions for poster presentations

Posters can be mounted on boards of 1.50 m height and 1.20 m width for display in the 1st floor of the conference building. Poster slots will be labelled with a number and your name. Drawing pins and adhesive tape will be provided. Please mount your poster as soon as possible after your registration at the desk. There will be a poster session on Wednesday, 27.09.2017 (15:50 – 16:30 h) and on Thursday, 28.09.2017 (11:00 – 11:40 h) Please stand next to your poster during the poster session to answer questions.

CONFERENCE PROGRAMME

AGENDA

Wednesday, 27th September 2017

Time	Lecture Hall 4	Lecture Hall 3	Lecture Hall 2
08:00-09:00	Registration		
09:00-09:20	Welcome		
	Opening Session: Key Speakers		
09:20-09:50	The contribution of paludiculture to climate change mitigation and adaptation **Hans Joosten**		
09:50-10:20	Climate-smart peatland use to improve livelihoods **Faizal Parish**		
10:20-10:50	Coffee Break		
	Session 1a: Case studies	**Session 2a: Biomass: production and utilisation**	
10:50-11:10	Lesson learned from paludiculture practices in Indonesia **Hesti Tata**	New crops for wet peatlands: Using the Database of potential paludiculture plants (DPPP) to preserve peat soils **Susanne Abel**	
11:10-11:30	The wavering path to paludiculture in Indonesia **Wim Giesen**	Using reed and *Typha* as building material, best practice tests on a realistic house restoration project **Aldert van Weeren**	
11:30-11:50	The review of the results of performed EU projects on reed and meadow grasses in Estonia and Finland **Ülo Kask**	Impact of papyrus harvesting and flooding on regeneration and biomass among open access wetlands: Implications for wetland management in changing climate **Joab J.L. Osumba**	
11:50-12:10	Biomass and pathways for utilisation of reed in the Ili Delta, Kazakhstan **Niels Thevs**	Let it grow! *Sphagnum* biomass production on rewetted cut-over bog and bog grassland in Germany **Greta Gaudig**	

AGENDA

Time	Lecture Hall 4	Lecture Hall 3	Lecture Hall 2
12:10-12:30	The great fen - a lowland peatland restoration **Lorna Parker**	Paludicrop choices suit rather stakeholder preferences than matching soil nutrient levels and hydrological regimes – experience from 5 Dutch cases **Christian Fritz**	
12:30-14:30	Lunch and technics exhibition		
	Session 3a: **Greenhouse gas emissions**	**Session 4a:** **Economy and society**	**Session 5a:** **Genetic and species diversity**
14:30-14:50	Vegetation as a proxy for GHG emissions from peatlands: an update of the GESTlist **John Couwenberg**	Economics of paludiculture: Sphagnum farming, reed harvesting and cattail cultivation **Sabine Wichmann**	Growth response of paludicrops to fertilization **Brian Sorrell**
14:50-15:10	Development and trial of an evaluation tool for the identification of the spatial potentials of paludicultures – an approach for the reduction of agricultural greenhouse gas emissions **Anna Schlattmann**	A business case for reed as a renewable resource **Frank W. Croon**	Paludicrop plants have invasive traits - prevention is better than cure **Carla Lambertini**
15:10-15:30	The contribution of drained organic soils to the globally emitted greenhouse gases and emission hotspots **Alexandra Barthelmes**	Biomass harvest on wet peatlands – assessment of different harvesting regimes using a labor time classification based model **Tobias Dahms**	Will biomass oriented conservation actions only further threaten world's largest refuge of a globally threatened passerine? A case for Zvaniec fen mire (Belarus), the Aquatic warbler and reed winter burning and mowing **Viktar Fenchuk**
15:30-15:50	Rewetted peatlands with benefits: dispatch from Ireland´s monitoring network **Florence Renou-Wilson** (cancelled)	Better Wetter: linking spatial adaptation to regional transitions **Ivan Mettrop**	Summer or winter? Ten years of mowing in Rozwarowo marshes and Peene valley - results on vegetation and breeding birds **Franziska Tanneberger**
15:50-16:30	Coffee Break and presentation of posters		

AGENDA

Time	Lecture Hall 4	Lecture Hall 3	Lecture Hall 2
	Session 3b: Greenhouse gas emissions	**Session 4b: Economy and society**	**Session 5b: Genetic and species diversity**
16:30-16:50	Paludiculture and greenhouse gases: case studies from three sites in northern Germany **Anke Günther**	Applying the concept of societal relationships with nature: insights for paludiculture and rewetting projects **Uta Berghöfer**	Species protection by paludiculture: *Sphagnum* cultures as surrogate habitats **Matthias Krebs**
16:50-17:10	Greenhouse gas balance of paludiculture for biogas production **Poul Erik Laerke**	Perspectives for agriculturally used drained peat soils: comparison of the socio-economic and ecologic business environment of six European countries **Christoph Buschmann**	Performance of *Sphagnum* species in experimental extracted peatland restoration **Edgar Karofeld**
17:10-17:30	Cutting-of or salting-down? Promising management tools to improve the carbon footprint of paludicultures **Christian Fritz**	Applying systems analysis to evaluate the use of Jelutung (*Dyera* sp.) as an option for the sustainable use of peatlands in central Kalimantan **Johan Kieft** (cancelled)	Protection for optimal *Sphagnum* growth **Martha Graf**
17:30	Summary and feedback	Summary and feedback	Summary and feedback
20:00	Conference Dinner		

AGENDA

Thursday, 28th September 2017

Time	Lecture Hall 4	Lecture Hall 3
08:00-09:00	Registration	
	Opening Session: **Key Speakers**	
09:00-09:40	Peatland restoration and paludiculture for clean and safe water **Ab Grootjans**	
	Session 6a: **Quality and quantity of water and nutrients**	**Session 2b:** **Biomass: production and utilisation**
09:40-10:00	Nutrient recycling in rewetted peatlands used for paludiculture **Jeroen Geurts**	Sustainable harvesting of *Sphagnum magellanicum* moss in Chile: a case analysis **Christel Oberpaur**
10:00-10:20	The influence of nitrogen input on biomass yield and nutrient sequestration in rewetted peatlands **Renske Vroom**	From natural peat moss to a commercial growing media constituent **Jan Felix Köbbing**
10:20-10:40	Nutrient preferences and limitations of paludicrops: insights from the photosynthesis-nitrogen relationship **Brian Sorrell**	Combustibility and nutrient export potential of biomass from rewetted fens in North Eastern Germany **Claudia Oehmke**
10:40-11:00	Managing nutrient and carbon release from inundated peatlands **Dominik Zak**	Three phase technology of harvesting and transportation of biomass from wetlands to nearby warehouses **Adam Dubowski**
11:00-11:40	Coffee break and presentation of posters	
	Session 6b: **Quality and quantity of water and nutrients**	**Session 2c:** **Biomass: production and utilisation**
11:40-12:00	Azolla farming on rewetted peat soils **Alfons Smolders**	The potential of the paludiculture crop *Typha* in a dairy farming system: nutritional values and biomass yield driven by harvesting date and stand age **Jeroen Pijlman**
12:00-12:20	Sphagnum farming initiatives in Canada: an overview **Sandrine Hugron**	Cattail products for a mass market: insulation material based on cattail **Robert Schwemmer**
12:20-12:40	The water balance of a Sphagnum farming site in Northwest Germany **Kristina Brust**	*Typha angustifolia* as a basis for the development of a new building material with multiple environmental and practical advantages **Martin Krus**

Time	Lecture Hall 4	Lecture Hall 3
12:40-13:00	Sphagnum farming in a eutrophic world: the importance of optimal nutrient stoichiometry **Ralph Temmink**	Integrated management of invasive cattails as biofuel and as a wetland management strategy in the Northern Great Plains of the United States **W. Daniel Svedarsky**
13:00-14:30	Lunch	
	Session 1b: **Case studies**	**Session 7:** **Legal and policy framework: incentives & constraints**
14:30-14:50	Reed-based renewable energy development in the Danube and Dniester deltas of Ukraine, Moldova and Romania **Paul Goriup**	Implementing paludiculture - How we can avoid land-use conflicts? **Christian Schröder**
14:50-15:10	What we have learnt from five years of paludiculture in a mediterranean peatland (Tuscany, IT) **Vittoria Giannini**	Impacts of the EU Common Agricultural Policy and the EU climate policy on the mitigation of greenhouse gas emissions from drained peat soils **Bernhard Osterburg**
15:10-15:30	Sustainable watersheds to renewable energy: *Typha* harvesting for nutrient management, wetland restoration and sustainable low carbon energy **W. Daniel Svedarsky**	Promoting paludiculture in the next Common Agriculture Policy framework **Annette Freibauer**
15:30-15:50	How to apply best practise of wet peatland use for common practise? Learning from existing approaches in Germany **Anke Nordt**	Is Europe ready for paludiculture? Implications of the EU regulatory environment **Jan Peters**
15:50-16:30	Coffee break	
16:30-18:00	Discussion	
18:00	Summary of discussion and concluding remarks	
20:00	Network evening	

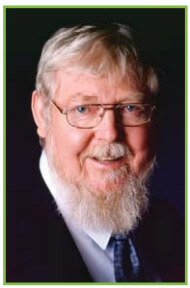
Art exhibition "RUMOOREN" - Art meets mire

„RUMOOREN - Kunst trifft Moor" is the title of an art exhibition initiated by the Greifswald Mire Centre (GMC) in cooperation with the Caspar-David-Friedrich-Insitut of Greifswald University. "RUMOOREN!" shows contributions by 20 artists and illustrate peat and peatlands in new perspectives.
Can art and culture contribute to show the ecological complexity of peatlands and the importance of their sustainable use? Can they thus prepare the ground for climate protection through peat protection? Is not social exchange essential to gain more acceptance and understanding for peatland protection, e.g. in Germany? These questions and thoughts caused the GMC to initiate the art competition and exhibition „RUMOOREN - Kunst trifft Moor".

The vernissage with award ceremony will take place at 24th of September 18:00 h at the Caspar-David-Friedrich Institute, Bahnhofstraße 46.
The exhibition runs from 24th September to 8th October 2017.
Opening hours during the conference 25th to 28th September: 08:00 – 20:00 h
Opening hours 29th September - 8th of October: daily 12:00 – 18:00 h.

Peatlands of Germany - a personal experience report with pictures

Speaker: Prof. em. Dr. Michael Succow
After the excursions at 26th of September at 20:00 h in the lecture hall / Loefflerstraße



We will go on a journey from the bogs of Northwestern Germany, along the mires of the Southern Baltic Sea area up to the central German uplands and the Alps.
We will hear about dramatic fates of mires and possibilities of their revitalisation.
Michael Succow is a biologist, landscape ecologist and influential advocate for nature conservation at the national and international level. For many years he was head of the Institute of Botany and Landscape Ecology at the University of Greifswald. Michael Succow was instrumental in developing the

programme of protected areas of the new German federal states after 1989 as well as in shaping the Greifswald study courses and research avenues in landscape ecology. In 1997 he was granted the “Right Livelihood Award” for his engagement in nature conservation worldwide. After his retirement he devoted his time to establish the Michael Succow Foundation.

Technics exhibition

During the conference different manufacturers, project developers and research institutes will present their products and services.
The exhibition includes the presentation of harvesting equipment for wet peatlands on the Greifswald market square on Wednesday 27th of September (during the extended lunch break) and a permanent indoor exhibition of wetland products, projects and harvesting equipment. In addition, during most excursions biomass harvesting and processing equipment will be shown.

Technics exhibition at the Greifswald market square during RRR 2013

Network evening

The networking evening (28th of September) starts at 19:30 h with drinks, barbecue (meat and vegetables) and fish rolls (at your own costs) at St. Spiritus, a historical churchy hospital, which hosts a cultural centre for nearly 30 years now. We will have some music and you can get in contact with fellow participants during our “peatland world café”. We hope you will have an inspiring evening!
Location: St. Spiritus, Lange Straße 49/51

Get in contact with important paludi-crops @ Greifswald Botanical Garden

The Greifswald Mire Centre established an exhibition on paludiculture plants at the Botanical Garden of Greifswald University. The already existing `Paludarium` (exhibition of wetland plants) has been updated and extended by plant containers with additional important paludiculture plants. Three categories of plants are shown:

I. paludiculture plant = plants that can be used in paludiculture. Positive experiences with them have been made

II. potential paludiculture plant = plants, which may play a role for paludiculture but still have to be researched in detail (effect on greenhouse gas emissions, peat conservation)

III. useful wetland plants = their cultivation in peatlands is not peat conserving (e.g. annual rotation necessary, belowground plant parts are used or constant high water tables are not tolerated)

Over 40 plants are described on boards with illustrations and information on its use. In addition, a large information board introduces the concept of paludiculture and the history of research on paludiculture in Greifswald. Its beginning dates back more than 150 years: In 1863 the founder of the Botanical Museum Julius Münter published an article on *Zizania aquatica* and mentioned a potential cultivation on the "lower meadows" near Greifswald. Since 1995 14 paludiculture projects on fens or bogs have been conducted by the GMC.

Stroll around in the Botanical Garden (Münterstraße 2, Greifswald) and get to know the exhibition boards. Opening hours are Monday to Friday from 09:00 h to 15:45 h and at the weekends from 13:00 h to 18:00 h.

Bog bean (*Menyanthes trifoliata*) – the leaves are used as medicine

SESSIONS

Abstracts Oral Presentations

OPENING SESSION: Key Speakers

Wednesday, 27th September

09:20 - 09:50 | The contribution of paludiculture to climate change mitigation and adaptation
Hans Joosten

09: 50 - 10:20 | Climate-smart peatland use to improve livelihoods
Faizal Parish

Thursday, 28th September

09:00 - 09:40 | Peatland restoration and paludiculture for clean and safe water
Ab Grootjans

The contribution of paludiculture to climate change mitigation and adaptation

Joosten, Hans
University of Greifswald, Institute of Botany and Landscape Ecology, partner in the Greifswald Mire Centre, Greifswald, Germany

Globally, drained peatlands are responsible for 5 % of all anthropogenic greenhouse gas emissions. In 50 countries drained peatlands emit > 10 %, in 25 countries even > 50 % compared to national emissions from fossil fuels and cement. Therefore, peatlands must play a major role in reaching the targets of the Paris Agreement. The root cause of peatland emissions lies in agriculture, which had its cradle in steppes and semi-deserts and consequently transforms mires into dry landscapes. The results are everywhere the same: gigantic greenhouse gas emissions and other forms of severe environmental damage. Sustainable utilisation of peatlands appears only to be possible under wet conditions. Paludiculture aims at reducing drainage-induced emissions, preserving the peat body as a sustainable base of production, while generating marketable products. The keynote gives an overview of climate change mitigation and adaptation perspectives in various parts of the world, discusses legal, political, and economic obstacles and challenges, and presents a way forward for the implementation of paludiculture as an important climate change mitigation and adaptation strategy.

Keywords: greenhouse gas emissions, peatlands, paludiculture, climate change mitigation

Prof. Dr. Hans Joosten:

Hans Joosten studied biology and worked as researcher and policy officer in the Netherlands. Since 1996 he leads the Department of Peatland Studies and Palaeoecology of Greifswald University (Germany), since 2008 as an Extraordinary Professor. A key topic of his research group is the development of paludiculture (a term he coined in 1998). In 2016 he, together with Wendelin Wichtmann and Christian Schröder, edited the first textbook about paludiculture. Hans Joosten is Secretary-General of the International Mire Conservation Group and since 2009 intensively involved in UNFCCC and IPCC, especially with respect to emissions from organic soils, and in FAO in advancing climate-responsible peatland management. In 2013 he was awarded the European CULTURA Prize for Sustainable Land Use and the German Federal Research Award Sustainability for the project Vorpommern Initiative Paludiculture.

Climate-smart peatland use to improve livelihoods

Parish, Faizal
Global Environment Centre, Petaling Jaya, Malaysia

Globally large areas of peatland have been targeted for conversion to agriculture and intensive forestry activities which have been one of the main drivers for peatland degradation. Peat extraction for energy and horticulture is another significant but smaller scale use. In Southeast Asia, there used to be nearly 25 million ha of peatland which was naturally vegetated with diverse peat swamp forest with more than 250 species of trees many of which have significant socio-economic value. More than 70% of this peatland has been heavily exploited and degraded and large areas converted to monoculture plantations of Oil Palm and Acacia. Many areas have been cleared, drained and burnt but subsequently abandoned due to inappropriate land development approaches. Some 10-15 million ha of degraded peatland is found in the region with more than 4 million ha burnt repeatedly in recent years - constituting one of the most important sources of GHG emission globally. The rewetting and rehabilitation of these peatlands provides a major opportunity for expansion of paludiculture in the region. There are more than 50 species of tree that are potentially suitable to be cultivated in rewetted peatlands - but large scale cultivation is still at a relatively early stage. The presentation will highlight initial progress and future opportunities and challenges for paludiculture in the region.

Keywords: peatland degradation, rehabilitation, oil palm, paludiculture, South East Asia

Faizal Parish:

Faizal Parish has been the Director of the Global Environment Centre, a Malaysian non-profit organisation working throughout East and Southeast Asia on forest and peatland management, biodiversity, water resources and climate change since 1998. He is originally from the UK but is currently a Malaysian Permanent Resident and has been living in Malaysia since 1983. He is a wetland ecologist with more than 30 years' experience in assessment, management and restoration of peat swamp forests, mangroves and river systems. He has worked with the ASEAN Secretariat since 2000 to establish the ASEAN Peatland Management Initiative and ASEAN Peatland Management Strategy 2006-2020 (APMS) and the ASEAN Programme on Sustainable Management of Peatland Ecosystems 2014-2020 (APSMPE) – all key ASEAN initiatives to conserve peatland biodiversity and ecosystems. Faizal Parish has been actively working on peatland and biodiversity conservation in South East Asia since 1983, leading assessments of wetland biodiversity in many ASEAN Member States. He coordinated a global assessment on peatlands biodiversity and climate change in association with CBD from 2003-2008. He was the Co-chair of the Roundtable of Sustainable Palm Oil (RSPO) Peatland Working Group (2009-2012) and developed the RSPO Manual on Best Management Practice for management and rehabilitation of natural vegetation associated with oil palm cultivation on peat. He is a member of the International Mire Conservation Group for more than 10 years.

Peatland restoration and paludiculture for clean and safe water

Grootjans, Ab
Radboud University Nijmegen, Faculty of Science, Aquatic Ecology & Environmental Biology, Nijmegen, The Netherlands

The area of rewetted peatlands in Europe is still small, but increasing - mainly because agricultural and silvicultural use of many peatland areas is economical less interesting. In many EU countries the continuation of agricultural use in such areas is driven by subsidies. In other words, citizens that do not directly profit from the intensive drainage of wetlands are paying the bills. And the costs of maintaining agricultural use in drained peatlands are increasing due to subsidence of the peat soils. That is why in densely populated areas, such as in the Netherlands, such areas are now used to prevent flooding in cities due to more intensive rain events during summer. The effects of these global change initiated events can be reduced by storing large amounts of surface water in nature areas and in low-lying agricultural areas on peat. This calls for alternative use of such areas. Paludiculture is by far the most sensible thing to do; use these areas wet. However, new investments in infrastructure and in modern equipment to harvest these areas are urgently needed. I propose that money that is now spent on continuing the environmental unfriendly way of land use (subsidies to both farmers and nature protection agencies) has to be transferred to organisations and private companies that are willing to use peatlands in a more sustainable way.

Keywords: rewetting of peatlands, alternative use, paludiculture, subsidies

Ab Grootjans:

Ab Grootjans worked at the University of Groningen between 1975 and 2016 and at the Radboud University Nijmegen between 2007 and 2017. His main field of expertise is ecohydrology of wetlands. He dealt with projects ranging from ecohydrological approaches on the landscape scale to very detailed research on the habitat scale. For example, he worked on the restoration of small dune wetlands along the Dutch and German coast and on developing new strategies for a more natural and dynamic coastal development. His work on the restoration of damaged peatlands helped improving restoration activities in various parts of the world including the former GDR, Slovakia, Latvia, Russia, Ireland, Tierra del Fuego, Japan, Australia and South Africa. He has also been active in the Dutch Knowledge network of researchers and managers (OBN) aimed at developing restoration projects in the Netherlands (1990- 2015).

SESSION 1: Case studies

Pilot projects and best practise examples play a vital role for implementing paludiculture at large scale. Pioneers adapt traditional uses, gain first experience with new cultivars or new processing avenues, and develop skills in establishing, managing, harvesting and using wetland plants. Such demonstration projects are invaluable for gathering hands-on knowledge. At the same time, working beyond experimental scale is essential for researchers to get real-life data on economics and side effects, for deriving sound recommendations and for vividly communicating paludiculture to farmers and politicians. We look forward to a wide range of case studies from various countries.

Wednesday, 27th September

10:50 - 11:10 | Lesson learned from paludiculture practices in Indonesia
Hesti Tata

11:10 - 11:30 | The wavering path to paludiculture in Indonesia
Wim Giesen

11:30 - 11:50 | The review of the results of performed EU projects on reed and meadow grasses in Estonia and Finland
Ülo Kask

11:50 - 12:10 | Biomass and pathways for utilisation of reed in the Ili Delta, Kazakhstan
Niels Thevs

12:10 - 12:30 | The great fen - a lowland peatland restoration
Lorna Parker

Thursday, 28th September

14:30 - 14:50 | Reed-based renewable energy development in the Danube and Dniester deltas of Ukraine, Moldova and Romania
Paul Goriup

14:50 - 15:10 | What we have learnt from five years of paludiculture in a mediterranean peatland (Tuscany, IT)
Vittoria Giannini

15:10 - 15:30 | Sustainable watersheds to renewable energy: *Typha* harvesting for nutrient management, wetland restoration, and sustainable low carbon energy
W. Daniel Svedarsky

15:30 - 15:50 | How to apply best practise of wet peatland use for common practise? Learning from existing approaches in Germany
Anke Nordt

Lesson Learned from Paludiculture Practices in Indonesia

Tata, Hesti[1]; Harun, Marinus[1]; Artuti, Hanna[3]
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[2] *Forest & Environment Research & Development Institute of Banjarbaru, South Kalimantan Province, Indonesia*
[3] *University of Tanjungpura, Agriculture Faculty, Forestry Department, Pontianak, West Kalimantan Province, Indonesia*

Indonesia covers a large area of peatlands, about 14.9 million ha. Peatlands in Indonesia distribute in three big islands, viz. Sumatra, Borneo and Papua. The local communities who live in peatlands have been utilising natural resources from peatlands, and cultivating peatlands using traditional knowledge for many years. However, mismanagement and over-exploitation of peatlands have changed the natural ecosystem of peatlands into degraded peatlands. After suffering from peat fire disasters in 2015, the Government of Indonesia has taken serious action on degraded and burnt peatland restoration. Paludiculture offers a better management of degraded peatlands. Paludiculture practices in Indonesia are site specific and based on the typology of peatlands. Different paludiculture practices have been identified in four provinces of Sumatra and Borneo islands, e.g. Jambi, South Sumatra, West Kalimantan, and Central Kalimantan. We will discuss the lesson learned of paludiculture practices from the four provinces.

Keywords: agroforestry, cultivation, peat swamp, Sumatra, Kalimantan

The wavering path to paludiculture in Indonesia

Giesen, Wim
Euroconsult Mott MacDonald, Arnhem, The Neatherlands

Peat swamps formerly extended over 13Mha on Indonesian Borneo and Sumatra, and until the 1980s they were largely forested ecosystems. Since then they have been logged, drained, and converted. They are also severely degraded and are a major source of carbon emissions. Paludiculture is recommended as a sustainable alternative, but its promotion has not been easy. The term 'paludiculture' was unheard of in Indonesia until recently, although extensive sago cultivation on undrained deep peat has been onging for more than a century, mainly on remote islands off the east coast of Sumatra. Other forms of cultivation on deep peat are either drainage-based, ignore the need for full rewetting, actively aim at ultimately removing peat by burning and draining, or are accidentally sustainable.

With 500+ useful species and 80+ non-timber forest product species with a major economic use, the peat swamp flora has significant potential for paludiculture. However, linking the cultivation of NTFP-producing peat swamp species to the rewetting of degraded peatland has stalled. A common view in Indonesia at present is that full rewetting is a 'radical' solution being promoted by conservationists, while 'managed drainage' is regarded as a sensible and sustainable compromise. What has not been helpful is that Government regulations on peatland management (PP71/2014; PP57/2016) specify that peat may be drained to 40cm depth, a leniency that has been seized upon by various agencies. However, this level of drainage can

only slow down but not stop degradation, nor can it stop fires and flooding. At the same time, some national scientific institutions promote "careful" water management (as used by the plantation industry) as a sustainable solution. Particularly confusing has been the promotion of a wide range of drainage requiring species in peatland by key agencies and NGOs that wrongly tout these as sustainable alternatives to oil palm and Acacia.
What is needed are good and well documented Indonesian examples of paludiculture on fully rewetted peatland to demonstrate that this approach can indeed be productive and financially viable. At the same time, unsustainable approaches need to be documented and exposed for what they are, simply unsustainable land use systems.
Linked to Berbak Green Prosperity Partnership Programme project, largely funded by MCA-Indonesia
Keywords: Indonesia, non-timber forest products, plantations, policies

The review of the results of performed EU projects on reed and meadow grasses in Estonia and Finland

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A number of EU funded projects in Estonia and Finland have performed to build good practice and facilitate knowledge exchange on related issues of Common Reed (*Phragmites australis*), largely at regional scales. The reed work should be aimed at synergy between the cutting of reed beds for biodiversity, water protection, local and regional solutions for harvesting of reeds, to help create biomass fuel, construction material, and soil improvement.
The ELY Centre for Southwest Finland has been the main facilitator of several cooperation projects in the Nordic-Baltic area. Interdisciplinary INTERREG IIIA project "Reed strategy in Finland and Estonia" 2005-2007 produced several practical publications connected with sustainable planning and use of reed (Read up on Reed!, Reed Energy etc). This project was followed by the COFREEN project "Concepts for using reed biomass as local bioenergy and building material", (funded under INTERREG IVA 2010-2013, applicant Turku University of Applied Sciences) which produced e.g. a Guidebook of Reed Business. The European Agri-project VELHO (2010-2014) carried out by the ELY Centre in Southwest Finland introduced guide for multi-purpose planning of Finnish coastal areas.
The research group of Water and Environmental Technology at Tallinn University of Technology participated at the INTERREG IVB Baltic Sea Region (BSR) Programme

project Submariner (lead partner The Maritime Institute in Gdansk), that aimed to assess innovative and sustainable uses of the Baltic marine resources, including common reed. The Submariner Compendium (2012) and Roadmap (2013) defined two key factors towards a blue-green economy in the BSR: 1) Smart combinations by integrating delivery of multiple products (e.g. construction material, bio fuel), and service (e.g. nutrient harvesting, habitat to maintain biodiversity); 2) System innovations by understanding the combined effects of resource uses and internalizing their social and environmental benefits.

Sustainable implementation requires careful planning, and consideration of the legal and policy framework for both biodiversity and bio fuels. As well as related issues such as agriculture and regional policy. EU Business and Biodiversity platform recommendations stressed that European countries should give greater attention to reed, and other non-wood, biomass under the Renewable Energy Directive and consider e.g. introducing standards for reed pellets. We should also classify reed as an agricultural product and thereby open the possibility of 'direct payments' for reed bed retention and management under the Common Agricultural Policy.

In this review paper, substantial results of performed EU projects on reed and meadow grasses are described. The outlook for the future is given also taking into account the new EU Renewable Energy Directive (Directive of the European Parliament and of the Council on the Promotion of the Use of Energy from Renewable Sources (recast)) and some other regulations such as LULUCF (Decision No 529/2013/EU of the European Parliament and Council) and Cascading use of biomass. These regulations have the potential to enhance the usage of reed.

http://www.europabook.eu/projects/reed-strategy-finland-and-estonia/,
http://projects.centralbaltic.eu/project/429-cofreen/
http://www.submariner-project.eu/index.php?option=com_content&view=article&id=233&Itemid=384 #Zeilenu

Keywords: reed, meadow grasses, EU projects

Biomass and pathways for utilisation of reed in the Ili Delta

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Central Asia is the region with the worldwide highest number of endorheic or closed river basins. Many of those river basins are transboundary ones. Within those river basins, riparian ecosystems, wetlands, and riparian forests, the most productive ecosystems, which offer a huge potential for utilisation ranging from biomass harvest to tourism. Following the desiccation of the Aral Sea, Lake Balkhash has become the largest lake of Central Asia with an area of 17,000 km^2. The Ili Delta, in total 8,000 km^2, is the largest natural delta and wetland complex of Central Asia. Some 70%

of the Ili River's runoff is generated in China, so, the Ili Delta is a show case for a wetland complex lying downstream in a transboundary river basin. The objective of this paper is to assess the area and distribution of the wetlands and *Phragmites australis* dominated reed vegetation as major natural ecosystems in the Ili Delta and their current and potential utilisation. An analysis of Rapid Eye satellite images revealed that there are wetlands and reed vegetation on a total area of 211,778 ha in the Ili Delta, 85400 ha are submerged reed beds, with a total estimated biomass of 869097 t. *Phragmites australis* is used as fodder and raw material. Currently, there are about 100,000 livestock grazing in the delta. The submerged reed is used by a factory for chipboards that could substitute wooden chipboards. Reed biomass is investigated as feedstock for bio-polymers, e.g. Poly-Lactat. In 2014, almost 10,000 tourists visited the delta. Most of all tourists come from Almaty, followed by Russia, other regions of Kazakhstan, and Europe (outside Russia).

Keywords: reed, land use simulation, cost benefit analysis, landscape services, water management, the Netherlands

Sustainable Watersheds to Renewable Energy: *Typha* harvesting for nutrient management, wetland restoration and sustainable low carbon energy

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For the last decade, IISD has pursued innovative strategies to manage water, land, and energy resources in the Lake Winnipeg Watershed, Canada. We proved harvesting *Typha* and other emergent plants that naturally take up nutrients (i.e. phosphorus) and contaminants - from marginal agricultural land, water retention sites, and drainage ditches - controls invasive plant species, improves and restores habitat, and reduces phosphorus loading downstream. Harvesting also produces abundant plant biomass to replace fossil fuels, generate CO_2 offsets, and provide cost-recovery. Since 2012, IISD's research in the Pelly's Lake water retention wetlands has demonstrated harvesting has major benefits when water retention for flood/drought control is combined with goals for wetland restoration, phosphorus control, and sustainable biomass energy. Over 100 ha of wetland habitat was restored through annual fall harvesting of *Typha* and managing water levels for flood control. Prior to management, this site had little to no habitat value. Now this restored wetland has a diversity of plants and birds. In 2015, IISD's Biomass Harvesting project reached large-scale implementation. With a growing demand for fuel pellets in Manitoba, 1,000 t of biomass was harvested, which removed 1.7 t of P and 14 t of N. Over 1,500 t of blended *Typha*:grass:wood fuel pellets were produced with excellent burn characteristics, ash (3%), and high heat energy (19.8 GJ/T). Fuel pellets were used for heating in large-scale biomass boilers and residential pellet stoves. This generated 5,000 t of CO_2e offsets and 50,000 GJ of heat energy - enough to heat 500 houses.

IISD also collaborates with the City of Winnipeg. In 2015 and 2016, 930 t of *Typha* harvested from City drainage ditches was diverted to compost. This captured 540 kg of P and 3,600 kg of N. Traditionally, this material would be left to decompose or sent to landfill.

Some publications related to IISD's *Typha* project and Bioeconomy Research Program: https://www.iisd.org/about/expert/richard-grosshans

Keywords: *Typha*, phosphorus, harvesting, bioenergy, carbon offsets, GHG emissions

Reed-based renewable energy development in the Danube and Dniester deltas of Ukraine, Moldova and Romania

Goriup, Paul[1]; Haberl, Andreas[2]; Smaliychuk, Anatoliy[3]; Kulchytskyy, Ivan[4]; Rubel, Oleg[5]; Ajder, Valeriu[6]; Ionescu, Camelia[7]; Grechulevich, Liliya[5]

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In the lower Danube, and Dniester floodplains, common reed (*Phragmites australis*) grows prolifically. A carefully designed and ecologically sustainable harvesting regime could use the reed biomass as a renewable energy source (briquettes, pellets, or biogas). Reeds grows best on land which is viewed as either unusable or extremely risky (due to regular flood events) for food production in the region. Hence it is a substantial biomass feedstock which avoids the 'food or fuel' debate, and has the potential to establish short carbon energy cycles in local communities.

Preliminary efforts to put such a system in place in different parts of the Danube delta area have indicated the feasibility of the approach, but gaining economic efficiency requires innovations in harvesting machinery, processing equipment, biomass boilers, and wetland management.

Accordingly, the ReedBASE project, led by institutions from Ukraine, Romania, Moldova, and Germany are developing a cross-border platform/cluster on the innovative use of wetland biomass in the lower Danube region. It is engaging relevant stakeholders and acts as an interface for the development and promotion of paludiculture.This project involvs the so-called "triple helix" institutions (government, business, and researchers) which already exist, and consolidating their collaboration.

Keywords: reed, energy, pellets, briquettes, paludiculture

What have we learnt from five years of paludiculture in a mediterranean peatland (Tuscany, IT)?

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In the last years, paludiculture has been considered a suitable solution for both environmental and economic problems arisen after the prolonged agri-silvicultural exploitation of the drained peatland throughout the world.

Since 2012, this management option has been tested in an experimental station located in a reclamation district within the Massaciuccoli Lake Basin (Tuscany, Italy) in order to i) treat the base-flow water delivered to the lake so as to limit the eutrophication, ii) reduce the soil organic matter mineralisation rate so as to slow down the subsidence, and iii) offer farmers an alternative to the traditional drainage-based cropping systems.

Within the experimental station comparing three different restoration strategies of a degraded peatland, an experimental trial of paludiculture (~ 5 ha wide) was established in spring 2012 with three perennial rhizomatous grasses (*Arundo donax*, *Miscanthus* x *giganteus*, *Phragmites australis*) and two woody species managed as short-rotation coppice (*Salix alba* 'Dimitrios' and *Populus* x *canadensis* 'Oudenberg'). A conventionally cultivated annual crop (maize) was used as control.

The aim of this study was to build a cross knowledge about the crops' suitability to the peculiar cultivation conditions by evaluating their productivity, their capability to uptake nutrients subtracting them from treated waters, and the quality of produced biomass in relation to the energy conversion (e.g. combustion, biogas).

Over the five years, *A. donax* showed the highest yields and nutrients uptakes even if in the last season it showed first symptoms of suffer due to prolonged saturation of the soil. Between the woody crops, *S. alba* showed a good performance differently from *P.* x *canadensis* that was severely affected by increasing percentage of mortality, year by year.

About the bioenergy destination, the woody species were more suitable for combustion than the grasses that were all promising for the biomethane production. In this case, the different harvest dates can significantly affect both the yields and the energy conversion efficiency.

Keywords: biomass production, nutrient uptake, biomass conversion, sustainable production

The Great Fen - A lowland peatland restoration

Carver, Kate; Parker, Lorna
The Wildlife Trust BCN, Cambridge, UK

A presentation on a landscape scale project being undertaken by the Great Fen project partnership, via the Wildlife Trust. The project is working to create a new wetland landscape, 3,700 ha, to surround and connect two National Nature Reserves - Woodwalton and Holme Fens.

Peats up to 4 m deep are being removed from intensive agricultural production, sown with grass and where possible the ground water table raised. Landforming has taken place to create new pools and conditions for reedbed colonisation.
The project is seeking solutions to water quality issues, and also recognises the need to continue farming on deep peats on which pump drainage is increasingly unsustainable. We are hoping to trial paludiculture exploring novel crops and novel uses, to see whether it is possible to create a paludicultural system which is economically viable, offers ecosystem service benefits and can be applied across the region and on other wetland creation projects.
www.greatfen.co.uk
Keywords: lowland peatland, habitat restoration, wetland creation, landscape scale, living landscape

How to apply best practise of wet peatland use for common practise? Learning from existing approaches in Germany

Nordt, Anke; Abel, Susanne; Peters, Jan; Wichtmann, Wendelin
University of Greifswald, Institute of Botany and Landscape Ecology, partner in the Greifswald Mire Centre, Greifswald, Germany

Best practice means an optimal, proved technique to deal with existing preconditions in an advanced way, which goes beyond the state of the art. Best practice examples show chances and possibilities as well as constraints and obstacles for the implementation of advanced approaches. They are crucial for knowledge transfer and further enhancing methods and improvement of techniques. To define best practice in wet peatland use, we made an estimate with a set of criteria for a number of wet peatland use related activities. This expert judgement assesses greenhouse gas reduction potential, further ecosystem services, nature conservation value, transferability into the area, economic feasibility and current framework conditions. With this assessment, we want to identify advantages and disadvantages of different best practice examples. Accordingly, potential gaps where to improve the best practice performance under given preconditions are determined. The presentation gives a short introduction into three practical approaches of wet peatland use in Germany: i) the heating facility in Malchin - that operates with hay bales from rewetted fen meadows, ii) the Sphagnum farming activities at Hankhausen bog - that aims to replace peat in growing substrates by mosses and iii) the *Typha* cultivation project- that produces *Typha* boards in Bavaria as a renewable innovative construction material. These examples are explored concerning their guiding idea and specific setup and existing constraints. Current obstacles are mainly costs, legal framework, further need of research and development and site availability. All analysed approaches include pro and con aspects concerning ideal wet peatland use. In total there are only few best practice approaches available in Germany. The existing ones have been developed because of engaged actors, a suitable window of opportunity or missing alternatives.

SESSION 2: Biomass|Production and Utilisation

Manufacturing products from wetland biomass requires specially adapted procedures ranging from plant cultivation, harvest, biomass transport and storage to biomass processing and use. This session will cover these topics from an application-technological point of view. Contributions can cover all steps from cultivation to the use of the product as well as studies assessing single steps, quality demands for biomass or properties of products. Presentations may also focus on harvesting or processing technologies and concepts. This session specifically addresses a broad audience of scientists and practitioners alike.

Hay bales, produced in wet meadows (photo: W. Wichtmann)

Wednesday, 27th September

10:50 - 11:10 | New crops for wet peatlands: Using the Database of potential paludiculture plants (DPPP) to preserve peat soils
Susanne Abel

11:10 - 11:30 | Using reed and *Typha* as building material, best practice tests on a realistic house restoration project
Aldert van Weeren

11:30 - 11:50 | Impact of papyrus harvesting and flooding on regeneration and biomass among open access wetlands: Implications for wetland management in changing climate
Joab J.L. Osumba

11:50 - 12:10 | Let it grow! *Sphagnum* biomass production on rewetted cut-over bog and bog grassland in Germany
Greta Gaudig

12:10 - 12:30 | Paludicrop choices suit rather stakeholder preferences than matching soil nutrient levels and hydrological regimes - experience from 5 Dutch cases (No abstract)
Christian Fritz

Thursday, 28th September

09:40 - 10:00 | Sustainable harvesting of *Sphagnum magellanicum* moss in Chile: a case analysis
Christel Oberpaur

10:00 - 10:20 | From natural peat moss to a commercial growing media constituent
Jan Felix Köbbing

10:20 - 10:40 | Combustibility and nutrient export potential of biomass from rewetted fens in North Eastern Germany
Claudia Oehmke

10:40 - 11:00 | Three phase technology of harvesting and transportation of biomass from wetlands to nearby warehouses
Adam Dubowski

11:40 - 12:00 | The potential of the paludiculture crop *Typha* in a dairy farming system: nutritional values and biomass yield driven by harvesting date and stand age
Jeroen Pijlman

12:00 - 12:20 | Cattail products for a mass market: insulation material based on cattail
Robert Schwemmer

12:20 - 12:40 | *Typha angustifolia* as a basis for the development of a new building material with multiple environmental and practical advantages
Martin Krus

12:40 - 13:00 | Integrated management of invasive cattails as biofuel and as a wetland management strategy in the Northern Great Plains of the United States
W. Daniel Svedarsky

New crops for wet peatlands: Using the Database of Potential Paludiculture Plants (DPPP) to preserve peat soils

Abel, Susanne; Schröder, Christian; Joosten, Hans

University of Greifswald, Institute of Botany and Landscape Ecology, partner in the Greifswald Mire Centre, Greifswald, Germany

Paludiculture ('palus' lat. for swamp) is the productive use of wet and rewetted peatlands in a way that preserves the peat body.

Next to the few well-established paludiculture plants, a wealth of wetland species are promising for paludiculture. The identification and description of these crops is essential for the wide implementation of paludiculture. The Database of Potential Paludiculture Plants (DPPP) was established to gather information on the variety of useful wetland plants and to present the first global overview of potential paludiculture plants. Currently the DPPP registers 1,131 plant species from all over the world, with an emphasis on the temperate zone.

However, which specific criteria define whether a species is suitable for paludiculture? Both ecological and economic features are relevant in this respect.

Paludiculture plants must grow under wet conditions, produce biomass in sufficient quantity and quality and – essentially - their cultivation must conserve the peat soil. The latter implies that only crops are cultivated that do not require regular tillage or other major soil works, which largely restricts the selection to perennial crops. Annual or short living crops can be cultivated only within a cover of permanent crops (e.g. sundew in peatmoss). Paludiculture also excludes plants, of which the belowground parts are harvested (e.g. *Acorus calamus* rhizomes or *Eleocharis dulcis* corms), as this would also imply too much soil movement. Additionally, an assessment of the market demand of the biomass helps to define profitability.

The assessment of the paludiculture potential is essential to avoid detrimental effects like peat degradation and greenhouse gas emissions. Cultivation of plants with a promising and good potential, in contrast, will likely contribute to peat preservation and simultaneously sustain the provision of marketable biomass. Species with a limited potential may also be suitable but may first require the development of suitable peat conserving crop management techniques or the promotion of a market demand.

Keywords: paludiculture plants, peat conservation, database

Using reed and *Typha* as building material, best practice tests on a realistic house restoration project

van Weeren, Aldert

Wetland Products Foundation, Amsterdam, The Neatherlands

Some years ago I bought an old house in the middle of the rewetted natural reserve area, Anklamer Stadtmoor in the NE of former eastern Germany, surrounded by natural wild grown fields of reed and *Typha*, and I realised that encountering Prof. Hans Joosten from nearby Greifswald Mire Centre can be dangerously addictive.

His ideas in promoting peatland rewetting as an easy way out of nitrogen and CO_2 emission problems in agriculture makes sense, a lot of sense. Additionally, growing

Typha under (hydrological) manageable conditions allows for water retention during severe weather conditions, cleaning agricultural polluted waters and better conditions for wildlife (biodiversity) in general. In city planning, polluted air and dust contamination are a frequent problem and cultivating *Typha* in urban areas can make a huge difference for the local climate, for example in humidity, air quality, as well as general quality of living.

The efforts of Mecklenburg-Western Pomerania in peatland restoration are of good intention, but my personal opinion is that farmers and local inhabitants should be allowed to use these areas in the future. One should find ways to earn money with or within these projects. Times are changing. The price of a hectare in agricultural use increased by a factor of 20 to 30 over the last 25 years. Thus, future peatland rewetting here and in many other places in Europe will be increasingly costly. This is one of the reasons the acceptance of these projects is shrinking. So, leave the farmer on his land and help him financially with the transition towards growing wetland crops. Planned well, this transition gives plenty of *Typha* as a crop the second winter after rewetting. Using *Typha* on rich soils and water quality with plenty nutrients, and reed on poor soils with clean water tends to be a fitting solution. Aditionally, combining the two is a realistic possibility.

Typha latifolia, the common "cattail", is in fact an incredible plant. Growing in the shortest time with enormous biomass, it can be used as building material in more than one way. Meanwhile, we are learning about best practice in harvesting, using dry weather, and transporting to a sheltered space for further drying to a water content of 35 to 55%.

Typha is a clean and tough plant, which can be used as a building material in different ways. The seeds can be used as additional reinforcement in clay plaster, leaves to press (composite) boards which can be made fire retardant and the complete plant (seeds and leaves mixed) can be processed to cavity wall insulation. No additives are needed and it meets fire retardant class E or more! In contrast, wood fibres cavity wall insulation needs "brom salt" additives. Its habitat makes *Typha* resistant to fungi and rotting. The ability to take on humidity and later dry out again makes it unnecessary to use plastic based damp proof membranes in construction.

I noticed that after the Donaumoos project (Technical University Munich) for almost 15 years *Typha* was seen as a perfect building and insulation product. However, not much happened on the „open" market: no growers, no machines, and no wholesales. As a result, no production chain and no end users. That's when I said to myself, let's change that. So I took up the idea of insulating the old house with an outside wall of reed-composite plating (non burnable) backfilled with *Typha* cavity wall insulation. Had I known what I was heading for, I probably would have thrown the idea overboard. For instance, 100 square meters of (wild) plants in Germany are a biotope and strictly protected by federal law, only to be harvested with a special license. So please, listeners/readers of all kind, PUT *TYPHA* AND REED ON THE EU LIST OF AGRICULTURAL CROPS AS SOON AS POSSIBLE!

In close cooperation with the Paludiculture initiative, in Mecklenburg-Western Pomerania, and the Universities of Greifswald and Nijmegen, the first crop (1/2 ha)

of *Typha* was (hand)mown. Last winter nearly 2 ha were mown with a Seiga machine. The yield was about 4 to 5 t of dry material which are set to be processed in the Hanffaser Factory in Prenzlau. In doing so, we hope to give these outstanding sustainable wetland products a kick in the direction of being a widely accepted best choice building and/or insulation material. Biobased and c2c.
You can check for yourself on the excursion day, when we will show these materials and ongoing house restoration. Wetland products are THE choice for a cleaner, sustainable, and CO_2-free building!
To promote these products, to share our knowledge on growing, harvesting, processing, and untilisastin as well as and to help building a growing /end-user supply-chain we founded the wetland products foundation, seated in Amsterdam.
www.wetlandproducts.com
Keywords: reed, *Typha*, building material, construction material, best practice

Impact of papyrus harvesting and flooding on regeneration and biomass among open access Wetlands: Implications for wetland management in a changing climate

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Quantifying temporal macrophyte regeneration and biomass is critical to understanding the capacity of littoral wetlands to absorb the shocks of repeated macrophyte harvesting and flooding in wetland ecosystems. However, very little information of this kind is available to guide planning and sustainable management of papyrus-dominated wetlands in Africa. This study assessed post-harvest macrophyte regrowth and biomass accumulation using two harvesting regimes among three fringing littoral swamps of Winam Gulf Wetlands in Lake Victoria Basin, Kenya. The assessment has shed new light on the nature of macrophyte biomass regeneration. Results indicate that, macrophyte regeneration and biomass varied with the frequency of harvesting, and with inundation levels. Results also show a negative correlation between the frequency of macrophyte harvesting and macrophyte biomass. Productive variability on average was found to be very high between seasonal and monthly harvests. The results showed that monthly harvesting significantly reduces macrophyte biomass as compared to seasonal harvesting, leading to a rejection of the hypothesis that a wetland macrophyte regenerates faster if exploited more frequently. Seasonal harvesting was found to reduce macrophyte regeneration but does not appear to have a significant effect on macrophyte biomass. On average macrophyte regrowth and biomass was lowest in monthly harvest plots, moderate in disturbed plots, and highest in undisturbed plots. It was further observed that a hydrological manipulation is likely to be more facilitative to macrophyte regeneration than rejuvenative harvesting. Less inundated plots were more productive than more inundated plots, leading to a rejection of the hypothesis that a wetland macrophyte regenerates faster if more inundated. This finding has documented for the first time that the drivers of faster wetland macrophyte regeneration may be more hydrological than anthropogenic. Valuable information was generated which can

contribute to the design of a recovery program for the declining littoral wetlands of the Lake Victoria Basin. It is recommended that a harvesting regime which allows for macrophytes to fully regenerate should be explored, without unduly affecting the socio-economic imperatives of macrophyte exploitation. The results may also pave way for broader ecological research into environmental changes on the fringing wetland ecosystems in the area. The present results contribute to the building of an information base needed to guide wise use of the resource.

Keywords: papyrus, macrophytes, flooding, littoral wetlands, harvesting, regeneration, biomass

Let it grow! *Sphagnum* biomass production on rewetted cut-over bog and bog grassland in Germany

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Sphagnum farming allows sustainable and climate-friendly land use on bogs, while producing a renewable substitute for peat in horticultural growing media. We studied *Sphagnum* productivity on a long-term experimental *Sphagnum* culture established on a cut-over bog with strongly decomposed peat at the surface and on a bog formerly used as grassland with weakly decomposed peat at the surface, both sites situated in Germany.

Preparation of the sites included levelling of the peat surface, construction of an irrigation system, spreading of *Sphagnum* fragments, covering them with straw, and finally rewetting. Provided there was an adequate (80-95 %) initial cover of *Sphagnum* fragments, the most relevant variables for *Sphagnum* productivity were found to be water supply and regular mowing of vascular plants. As long as sufficient water was supplied, the dry biomass accumulation of the established *Sphagnum* lawn was high in both tested systems – at the formerly cut-over or grassland site - with values up to 6.9 t ha^{-1} yr^{-1}or 8.6 t ha^{-1} yr^{-1}, respectively.

www.sphagnumfarming.com

Keywords: Sphagnum farming, growing media, sustainable bog use, renewable resource

Sustainalble harvesting of *Sphagnum magellanicum* moss in Chile: a case analysis

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S. magellanicum moss has been harvested at Los Lagos Region, southern Chile, in ascending volumes since 1990, due to increase of international demand. A common overexploitation of peat bogs is observed in the region, especially at Chiloé Island. In 2013 a field guide was published, with guidelines to implement a sustainable management and harvest of *Sphagnum* moss in this area of the country, based on several previous researches. However, monitoring and confirming the effect of the proposed management requires long-term follow-up. This work describes the

experience of a farmer, placed at Calbuco province in the same region, who took over an overexploited peat bog, of about 6 ha in 2009 and adopted since 2012 the suggested guidelines. The bog was divided into 6 plots of 1 ha, which were harvested at different times, giving lag periods between each mosscollection. Annual yield of harvested moss was recorded since 2009, which is the last year when the bog was overharvested. In addition, since April 2016, environmental conditions were recorded by an automatic meteorological station. Moss growth was measured with cranked wires, and the water table monthly in three sectors of the peat bog. An average growth of 1.5 cm was observed at three sampling points, each with ten cranked wires, after 9 months. The average depth of the groundwater layer was 7.8 cm and the lowest reached 30 cm at the end of summer. Harvest yield indicate that with a lag period of 3 years 2.7 t ha^{-1} of dry moss was obtained, while with 5 years between interventions, the yield reached 6.6 t ha^{-1} in this bog. To obtain a theoretical maximum yield of 10 t ha^{-1} it would be necessary to delay the collection for 8 to 9 years in order to guarantee a sustainable exploitation.

Acknowledgements: Mr. Tomás Ovando, landowner
Project BIP 30422976-0, Innovation Fund for Competitiveness, financed by the Regional Government of Los Lagos.
Keywords: *Sphagnum* productivity, sustainable exploitation

From natural peat moss to a commercial growing media constituent

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Finding a sustainable alternative for peat in horticulture has become more and more pressing in recent years. So far, discussed substitutes either have insufficient properties, are not available in sufficient amounts, have a negative environmental impact themselves, or present a combination of all drawbacks. Consequently, growing peat mosses (*Sphagnum* spp.), the main component of bog peat, as a commercial crop, seems to be highly attractive option.

In 2015 Klasmann-Deilmann, together with its partners, started a research project in Lower-Saxony, Germany, with the goal to cultivate peat mosses as a growing media constituent after peat extraction on residual strongly decomposed peat. Findings so far show, that peat moss can be a very good substitute for peat in terms of its horticultural properties. However, the profitable sourcing of large amounts of *Sphagnum* mosses remains challenging.

Commercial cultivation of peat mosses has to overcome a number of challenges

1) Land competition is very high in Germany, as most residual bog-peatlands are used as grass- or farmland and most peat extraction areas are designated to become conservation sites.

2) The procurement of donor/inoculation material is difficult.

3) Colonization with weeds, the low productivity of mosses, the hydro management (irrigation, drainage, availability, quality), adapted harvesting technology and processing (drying, hygienization) harvested mosses are further hurdles to overcome.

The potential to obtain mosses from natural habitats, for example from Chile, Australia or Finland, is very limited and costly. In conclusion, there is potential in peat moss cultivation as a growing media constituent, but doubts arise regarding its economic efficiency. To enhance this type of paludiculture much stronger political and financial support is needed. | www.klasmann-deilmann.com

Keywords: *Sphagnum*, peat moss, paludiculture, bog, peat extraction, horticulture, growing media constituent

Combustibility and nutrient export potential of biomass from rewetted fens in North-Eastern Germany

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One aim of the project CLEARANCE is to analyse biomass utilisation options in wetland buffer zones with respect to nutrient export and biomass production, and therewith mitigate water pollution in connected river ecosystems. Paludiculture can be applied for wetland buffer zones as an integrative concept using biomass from wet peat soils. Solid biofuels are one option for biomass utilisation from paludiculture, but have to meet high quality standards to fulfill legal requirements. The late harvest in winter is a common practise to increase combustibility of solid-biomass, expecially for herbs and grasses. Critical elements for combustion will be reduced in the standing biomass by leaching through precipitation. Additionally some plant species reallocate nutrients to the rhizomes during autumn (f.e. Common Reed).

Combustion quality of Common Reed (*Phragmites australis*) and Sedges (*Carex* spp.) are also increased by a late harvest in winter. Common Reed showed low critical elemental concentration, with 0,5% N, 0,1% S and 0,08 % Cl (d.b.) in February. Sedges lost 95% of the total chlorine concentration, from 0.62 (summer) to 0.03 % (winter), but N and S decreased only slightly from summer (1.4 % N/0.21 % S) to the winter (1.24 % N/0.16 % S (d.b.)).

Coincidently, winter harvest of the plants goes along with lower yields and lower nutrient contents resulting in lower nutrient uptake potential. *Carex acuta* yield decreased from August (4.5 t/ha) to February (3 t/ha) with nutrient contents of 6 kg P/ha and 63 kg N/ha in August and 4 kg P/ha and 37 kg N/ha in February. *Phragmites australis* yields of the studied sites were relatively low with 6.5 t/ha (October) and 3.8 t/ha (February) in comparison to values from other studies in Northeast Germany that ranged from 2-12 t/ha (d.b.), in February. The measured biomass nutrient content was 4 kg P/ha and 50 kg N/ha in October, and 1.7 kg P/ha and 21 kg N/ha in February. Harvesting in early autumn is most appropriate to combine the production of solid biofuels with the removal of nutrients in water buffer zones. If nutrients export from the wetland buffer zone is the more important issue, harvesting should be realised in summer. This biomass with low quality for combustion can be mixed with high quality biomass (f.e. wood) or other kinds of pre-conditioning (washing, mechanical dehydration) are required.

Keywords: nutrient export, common reed, sedges

Three phase technology of harvesting and transportation of biomass from wetlands to nearby warehouses

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Many wetlands and fen peatlands in Poland require special care to restore and protect, as they are breeding areas for endangered bird species. Outdated tracked snow groomers, tracked trailers, and wheeled tractors are not as eco-friendly as expected. The Industrial Institute of Agricultural Engineering (PIMR) is developing innovative vehicles, tools, and technologies that will be more useful in formal paludiculture. Works were financed with funds: WND-POIG.01.03.01-00-164/09 and UOD-DEM-1-145/001.

We present equipment for three phase technology of biomass harvesting and transporting: 1) new mower unit mounted on a tracked vehicle, consisting of a mower with conditioner and a rake with tedder, 2) combination of tracked vehicles for non-stop swath collecting and forming biomass bales, and 3) vehicles that can serve as tractors of a “biomass-train” and can be used for towing biomass bales from the wetlands to temporary warehouses. In the mowing process biomass is cut and put in a special conditioner, where it is crushed and cut into smaller pieces. Next, swath is left in the field for a period of about 2-3 weeks - this is needed to secure natural seeding process and to ensure adequate biodiversity in the protected terrains. Non-stop swath collecting unit consists of a swath pick-up attachment and belt conveyors mounted on the tractor, a unit for forming bales is constructed on the trailer - it consists of spacious feeding hopper and round-bale press. Recently, number of tractors for biomass-train technology increased side by side all terrains vehicles. Preliminary results were presented on CIGR AgEng 2016 in Denmark and EcoSummit 2016 in France.

Tracked vehicles used for the three-phase technology have practically no impact on wetlands - they use biodegradable oil in power hydraulics, tracks made only grooved path (depth~30mm), biomass swath is collected in full and formed into bales, and bales are towed in eco-friendly way from wetlands to nearby warehouses.

www.pimr. poznan.pl /

www.pimr.eu

Keywords: biomass, tracked vehicles, trailer, mower, conditioner, swath, harvest round bale, biomass-train, transport, wetlands, protection, environment

The potential of the paludiculture crop *Typha* in a dairy farming system: nutritional values and biomass yield driven by harvesting date and stand age

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Introduction: In the Netherlands, 80% of the peat soils are drained for intensive grass production, resulting in undesired soil subsidence and increased CO_2-emissions. Growing *Typha latifolia* on rewetted peatland stops peat oxidation. However, information on the use of *Typha* as fodder in a dairy farming system is scarce. Therefore, objectives of the current work were to assess biomass production and nutritional values of *Typha*.
Material and methods: Plants were harvested from a natural stand at the Nieuwkoopse Plassen (NP), with a low density of 7.9 (SD 1.6) predominantly green tillers m^{-2}, and a newly spring planted stand with a density of 3.5 plants m^{-2} in Zegveld, created on a former grassland, after topsoil removal (10 cm) and rewetting. Water levels at both sites ranged between 15-30 cm above the soil surface.
Results: At NP, biomass yield in June was 1624 (SD 29) kg dry matter (DM) ha^{-1}. Plant crude protein (CP) and crude fiber (CF) contents were 95 (SD 10.4) and 320 (SD 25.5) g kg^{-1}, and in vitro digestibility of organic matter (dOM) was 51 (SD 3.2) %. This is much lower compared to fresh autumn grass harvested between 2011-2015 in the Netherlands (CP 181-207 g kg^{-1}, CF 181-207 g kg^{-1} and dOM 77.4-79.1%). At Zegveld, on 8 November *Typha* CP and CF contents were 163 and 226 g kg^{-1}, while at 30 November CP and CF contents were 119 and 269 g kg^{-1} suggesting senescence. Average DM yield at both harvesting dates was 371 (SD 4.7) kg ha^{-1}. *Typha* harvested at Zegveld was on average, relative to fresh autumn grass harvested between 2011-2015 in the Netherlands, richer in Ca (156%), Co (144%), and Se (500%), and poorer in P (54%), K (51%), Mg (79%), Cu (42%), and Zn (47%). The high Se content is especially interesting, since dairy rations on peat soils are generally low in Se. Furthermore, low P contents allow decreasing dietary P contents which can reduce farm born P loads to the environment.
Conclusions: Nutritional values of *Typha* were, except for several minerals, inferior to fresh autumn grass. Mixing *Typha* fodder in grass based diary rations holds promising aspects, but further research is needed on nutritional and environmental effects at animal and farm level.
Keywords: *Typha latifolia*, biomass yield, nutritional value, harvesting date, dairy farming

Cattail products for a mass market: Insulation material based on cattail

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Naporo Klima Dämmstoff, Perg, Austria

Project report of the founder of a green insulation company including the following topics:

- From the field to the customer - production and distribution barriers
- Market situation of sustainable insulation materials.
- Image and reality of sustainable building materials.
- Spotting the benefits - USP vs price

Keywords: Cattail insulation, green building, insulation material, natural fibers, *Typha*

Typha angustifolia as a basis for the development of a new building material with multiple environmental and practical advantages

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Because of its enormous growth rate and yield, cattail is optimally suited as raw material for industrial use. *Typha* stocks comprise resilient, natural monocultures with an annual production rate of 15 to 20 tonnes of dry matter per hectare. Due to the special structural properties of cattail (*Typha*), building materials can be produced that offer a combination of insulation and strength, which is unique on the market. The leaves of *Typha angustifolia* have a fiber-reinforced supporting tissue filled with soft open-cell spongy tissue, which provides for amazing statics and an excellent insulating effect. Using these features a magnesite-bound *Typha* board has been developed with a high strength and dynamic stability despite a low thermal conductivity of about 0.055 W/mK to solve energetic as well as static problems. This product contains only plant ingredients and a purely mineral-based adhesive and no further additives. This innovative building material possesses a lot of additional positive properties: renewable building material with a very high resistance to mould growth, simple processability with all common tools, low energy consumption in production, and its recyclability. The very high fire resistance of these is also an important advantage.

The first practical application of this material has been within the restoration of an old half-timber-framed building. With the *Typha* board as infill for the timber frames, and as an additional inside insulation layer an extremely slender exterior wall construction with wall heating was realized. The magnesite-bound *Typha* board was also applied successfully for interior insulation of masonry, where due to its hygric properties, and resulting fault tolerance the use of a vapour barrier could be avoided. With a sauna house, a modern wood-frame construction, for the first time a building construction has been realized which nearly meets the „cradle to cradle“ demands. This is the first new building where a material is used which unites all qualities relevant for construction in itself: static stiffening, heat insulation, sound insulation, moisture protection, and also fire prevention. Finally with the *Typha* board a small building has been established as self-supporting construction and was shown in Milano during the EXPO2016.

Keywords: *Typha*, sustainability, insulation, building material

Integrated Management of Invasive Cattails as Biofuel and as a Wetland Management Strategy in the Northern Great Plains of the United States

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On many public lands in the Great Plains region of northwest Minnesota, North Dakota, and Manitoba, cattail growth has far exceeded the 50:50 distribution recommended for optimum wetland wildlife habitat. It is perhaps, THE primary management concern of Minnesota wetland managers. Often the coverage of this mostly hybrid cattail (*Typha latifolia* X T. *angustifolia*) is over 90% and while a problem for wildlife, represents a substantial biofuel resource. In the 10 counties of northwest Minnesota, available biomass is estimated to be 18.5 M kg distributed on 38,000 ha of natural and artificial wetlands assuming a 50% harvest rate. Cattail control using mowing, herbicides, and burning methods is expensive and if harvest logistics can be improved, along with the development of biofuel markets, management would become much more affordable. Cattails have energy values comparable to wood pellets at 17 MJ kg^{-1}. Thus, cattails could be simultaneously managed for wetland wildlife, harvested for biofuel, generate carbon credits (at least in Canada), and serve as a partial substitute for fossil fuels to help mitigate climate change. Cattails may also extract phosphorous from runoff water in rivers feeding lakes and flood control impoundments that could be used for agricultural fertilizer; 20 to 60 kg of phosphorous have been removed per hectare of harvested cattails in Canada. Additionally, local rural economies could be boosted by harvesting a renewable energy resource, especially in states such as Minnesota which have no fossil fuels. Along with evaluation of harvesting techniques, responses of wetland wildlife to these management applications are being measured.
Keywords: cattail, *Typha*, wetland biofuel, wetland wildlife management, Northern Great Plains

SESSION 3: Greenhouse gas emissions

Measurements of greenhouse gas fluxes in mown peatlands have started very recently. There are still gaps of such measurements in certain peatland and vegetation types, and in particular under mowing or grazing. This session reflects the state of the art knowledge on greenhouse gas fluxes in wet and rewetted peatlands, present outcomes of current measurements in mown wet peatlands, and discusses hypotheses on greenhouse gas fluxes under various forms of paludiculture (e.g. reeds, reed beds, *Sphagnum* lawns) and different conditions (e.g. date of harvest, water tables, trophic conditions).

Wednesday, 27th September

14:30 - 14:50 | Vegetation as a proxy for GHG emissions from peatlands: an update of the GEST list
John Couwenberg

14:50 - 15:10 | Development and trial of an evaluation tool for the identification of the spatial potentials of paludicultures – an approach for the reduction of agricultural greenhouse gas emissions
Anna Schlattmann

15:10 - 15:30 | The contribution of drained organic soils to the globally emitted greenhouse gases and emission
Alexandra Barthelmes

15:30 - 15:50 | Rewetted peatlands with benefits: dispatch from Ireland´s monitoring network
Florence Renou-Wilson (cancelled)

16:30 - 16:50 | Paludiculture and greenhouse gases: case studies from three sites in northern Germany
Anke Günther

16:50 - 17:10 | Greenhouse gas balance of paludiculture for biogas production
Poul Erik Laerke

17:10 - 17:30 | Cutting-of or salting-down? Promising management tools to improve the carbon footprint of paludicultures
Christian Fritz

Vegetation as a proxy for GHG emissions from peatlands: an update of the GEST list

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Greenhouse Gas Emission Site Types (GESTs) were developed as a proxy to assess greenhouse gas (GHG) emissions and emission reductions from peatland rewetting projects in temperate continental Europe (Couwenberg et al. 2008, 2011). GESTs use vegetation as an integrative proxy for GHG fluxes. Vegetation is well suited for that purpose as it reflects long-term water tables, affects GHG emissions via assimilate supply, and aerenchyma, and allows for fine-scaled mapping.

Many new flux measurements have become available since we first introduced the GESTs. Whereas the original GESTs were based on 60, 140 and 128 annual flux measurements for CO_2, CH_4 and N_2O respectively we now have 236, 339 and 272 measurements for evaluation.

These flux data was grouped together with data on vegetation, mean annual water table, and other parameters, including land use, to arrive at classes that best describe GHG fluxes in association with a coherent set of site conditions. The resulting matrix allowed us to inter- and extrapolate flux values where direct measurements were not available.

We defined a total of 30 GESTs and 9 special GESTs. GESTs represent non-treed sites ranging from deeply drained to shallow flooded and nutrient poor to nutrient rich. Special GESTs represent aberrant sites for which GHG fluxes diverge from the general relationship with water table and vegetation or where the relationship between water table and vegetation is atypical. The special GESTs include sites with an only shallow peat layer that would not fit common definitions of peat soil (>30 cm thick layer with >35% organic material).

We present an overview of the GESTs and a meta-analysis of the available flux data.

Keywords: greenhouse gas emissions, meta-analysis, proxy, vegetation, bioindication

Development and trial of an evaluation tool for the identification of the spatial potentials of paludicultures – An approach for the reduction of agricultural greenhouse gas emissions

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Reducing greenhouse gas emissions caused by the land use on peaty soil could make great efforts on climate protection. If peatlands are rewetted to avoid high emissions, agricultural land use is no longer possible. An alternative, integrating the production of renewable raw materials and climate protection, is the “paludiculture”. But, methods for the capture and evaluation of spatial cultivation potentials for paludicultures are not yet developed.

Therefore, the target of the investigations presented here was to develop and to prove an evaluation tool which allows to identify the cultivation potentials of *Phragmites australis* and *Typha latifolia* as sample species. Additionally, the tool should enable the estimation of the potential for the reduction of agricultural greenhouse gas emissions due to the change of land use.
The tool was developed on the basis of the existing knowledge concerning the cultivation of reeds. Its concept is to enable the valuation of agricultural fields' suitability to the cultivation of reeds in northern Germany. It is based on a combination of normalised and argumentative evaluation techniques. There are four main topics dealt with: the general framework of environmental and nature protection legislation concerning the cultivation of reeds, the habitat requirements of the sample species, the technical demands for cultivation, and the potential of reducing greenhouse gas emissions.
The implementation of the tool was performed by a GIS-based analysis for two study areas located in Lower Saxony. In both study areas *Phragmites australis* has a more widespread range of possible cultivation sites than *Typha latifolia*. Thereby, the highest greenhouse gas diminutions can be achieved on fens used by arable farming, on which a rewetting can be realised completely. Among others, on grasslands the framework of environmental and nature protection legislation in Germany and Europe can heavily diminish the potential cultivation area of reeds.
Keywords: paludiculture, reeds, spatial potential for cultivation, GHG reduction

The contribution of drained organic soils to the globally emitted greenhouse gases and emission hotspots

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Peatlands cover only 3% of the global land surface. Some 15% of these peatlands have been drained for agriculture, forestry, and peat cutting, which leads to the release huge amounts of carbon. The '2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands' (IPCC 2014) offers up-to-date default emission factors for different land use types on organic soil and thus enables proper reporting. For this, realistic area data of drained organic soils was needed at a national scale as well.
The Global Peatland Database (GPD; hosted at the Greifswald Mire Centre) collates and integrates data on location, extent, and drainage status of peatlands and organic soils worldwide and contains publications, reports, observations, maps, pictures, and integrative analyses for 268 individual countries and regions. Moreover, it comprises growing coverage on geospatial data (paper and digital maps or GIS data). Based on this data, the area of drained peatland under different land use has been estimated for each country or region and used for emission calculation.
If adopting the default emission factors from IPCC (2014) globally, the emissions from drained and degrading peatlands (organic soils) amount to almost double the

amount of CO_2 emissions from aviation; even when emissions from peat fires are not included. By far the top single emitter of drained peatland related greenhouse gases is Indonesia, followed by the European Union and Russia. Some 25 countries are together responsible for 95% of global emissions from peatland drainage, excluding fires. Fires raise the importance of particularly Indonesia and Russian Federation. In 25 countries emissions from peatland degradation are over 50% of the emissions from fossil fuels and cement production combined, hence peatland emissions are of national significance.

Keywords: organic soils, peatlands, drainage, emissions, global coverage

Rewetted peatlands with benefits: dispatch from Ireland's monitoring network

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The NEROS project involved field-based studies that simultaneously quantified both biodiversity and climate mitigation benefits (i.e. GHG fluxes) across a network of drained and rewetted organic soils from various land use categories (LUC) including forestry, agriculture, and peat extraction.

We found the flora of the rewetted bogs was very similar to that of their natural counterparts in sites where initial drainage was the only disturbance. Both raised and blanket bogs that have been drained-only (not planted or cut) also exhibited the expected range of micro-habitats and species composition. On the other hand, an increased species number and/or macro-habitats was a negative indicator of rewetting projects in large and heterogeneous sites such as industrial cutaway peatlands. In the case of forested peatlands, site conditions prior to rewetting (dry forest soil) and methods utilised (leaving brash/felling material on site) strongly influenced the recovery of micro-habitats heterogeneity and indicator species such as bryophytes.

The rewetted nutrient poor industrial cutaway, domestic cutover, and grassland LUCs were net sinks of CO_2 (-1.04 to -0.40 t C ha^{-1} yr^{-1}) while the nutrient rich industrial cutaway and forestry LUCs were net sources (0.59 to 5.60 t C ha^{-1} yr^{-1}). Methane (CH_4) emissions were highest in the peat extraction LUC (173-197 kg C ha^{-1} yr^{-1}) and lowest in forestry (20-26 kg C ha^{-1} yr^{-1}).

Overall, in regard to biodiversity, the study demonstrated that environmental and management variables can influence species composition, and therefore regeneration of typical species of natural sites (biodiversity indicators of rewetted and restored peatlands). The same variables together with the vegetation composition will indicate whether the GHG emissions can be reduced and the biogeochemical functions returned to those characteristic of natural peatlands. This study has highlighted the climate benefits from rewetting degraded peatlands in terms of reduced GHG emissions,

the return of the C sequestration function characteristic of natural (non-degraded) peatlands in many cases, as well as increased biodiversity provision. However, rewetting of degraded peatlands is a major challenge and can be a balancing act between benefiting biodiversity and/or climate. We recommend priority LUCs for rewetting to maximise the synergy benefits of biodiversity provision and climate change mitigation.
www.ucd.ie/neros
Keywords: rewetting, bogs, Ireland, climate, biodiversity, LUC

Paludiculture and greenhouse gases: case studies from three sites in northern Germany

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Wet utilisation of peatlands is seen as a viable climate warming mitigation option, because it reduces the harmful effects of conventional agriculture on peat soils. However, as plants have been shown to significantly contribute to the greenhouse gas exchange in peatlands, manipulating the vegetation (by harvesting, sowing etc.) might alter the climatic effect of rewetted peatlands. Meanwhile, data on the greenhouse gas exchange of paludiculture systems is scarce.
Here, we present greenhouse gas data from three experimental paludiculture systems in northern Germany. In two fens –one rewetted more than 15 years ago and one naturally wet and under nature protection– different species of reeds and wet grasslands were harvested to simulate biomass production. In a peat bog that has been converted from drained grassland to a field with a controlled water table around ground surface *Sphagnum* mosses were cultivated to provide an alternative growing substrate for horticulture. In all systems we determined carbon dioxide, methane, and nitrous oxide exchange using closed chambers over two years.
The greenhouse gas balances were generally dominated by carbon dioxide and methane exchange. Two of the restored peatlands show greenhouse gas balances comparable to those of natural ecosystems, whereas the nature protection site emits greenhouse gases in the range of shallowly drained peatlands, due to generally lower water tables. Our data indicate that paludiculture systems may be particularly robust against the effects of weather extremes on greenhouse gas exchange. We did not find a negative short-term effect of biomass harvest or *Sphagnum* cultivation on net greenhouse gas balances. Therefore, paludiculture may likely provide a possibility to add economic value to restored peatlands while retaining the positive effects of rewetting for greenhouse gas mitigation.
Keywords: Sphagnum farming, carbon dioxid, methane, *Phragmites australis*

Greenhouse gas balance of paludiculture for biogas production

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Rewetting has been recommended to reduce CO_2 emission and to restore the carbon sink function of drained peatland. Paludiculture, the combination of peatland rewetting and biomass production, has gained interest as a possible land use option without losing agricultural land. Biogas production is one possible option if grass biomass is produced in paludiculture. However, more knowledge on suitable crops and their effects on the greenhouse gas (GHG) balance are needed. With intact soil cores (mesocosms) we have shown that the GHG emission from cultivation of reed canary grass (RCG), under controlled conditions can offset the GHG emission from a drained peat soil if the water table is raised close to the soil surface and at the same time producing 12 Mg ha^{-1} DM per year in two cuts. To support these findings, a new field experiment was initiated in 2015. The water levels of four plots established with RCG in 2013 on a fen peat soil were raised to soil surface by pumping water back from the ditch. Emissions of CO_2, CH_4, and N_2O were measured bi-weekly with opaque chambers. NEE of CO_2 was assessed with temperature controlled transparent chambers. Two cuts of the biomass in 2015 yielded 13.8 Mg ha^{-1} DM. The NEE from 5 March 2015 to 4 March 2016 showed that more than 22.9 Mg ha^{-1} CO_2 was taken up by the ecosystem. However, in the same period 21.0 Mg ha^{-1} CO_2eq of CH_4 and 2.5 Mg ha^{-1} CO_2eq of N_2O were emitted. A second year of measurements is currently being carried out. Based on two years priliminary results we may conclude that peat degradation at this agricultural field was reversed after rewetting, but at the same time we found a risk of high CH_4 emission.

This study was part of the CAOS project (ERA-net on Climate Smart Agriculture)
Keywords: reed canary grass, biogas production, carbon dioxide, methane, nitrous oxide

Cutting-of or salting-down? Promising management tools to improve the carbon footprint of Paludicultures

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The reduction of greenhouse gas emissions is a strong rational to rewet peat soils and to crop paludicultures creating Wetscapes. While CO_2 and N_2O emission largely

decrease upon high water levels CH_4 emissions rates often reveal a moderate to strong increase. CH_4 emissions can be reduced by either inhibiting production or promoting consumption (CH_4 oxidation). In this talk we present results from mesocosm experiments exposing soils from paludiculture fields to increased salinity and sod-cutting.

Experiments were conducted in 5 l containers filled with peat soils from formerly agricultural peat meadows exposed to sod-cutting in 5 cm steps down to 25 cm (top soil removal). Soils were also treated with 2 salinity levels. We followed methane emission and methane production in the course of 85-200 days. Methane emissions of treated soils were compared to with mesocosm planted with cattail (*Typha latifolia*) and common reed (*Phragmites australis*). We also measured soil chemistry parameters indicating redox potential in the mesocosm.

Sod-cutting proved to efficiently prevent CH_4 release reducing emissions from 704 mg CH_4 m^{-2} h^{-1} (se 252) to 106 mg CH_4 m^{-2} h^{-1} (se 88) and 19 mg CH_4 m^{-2} h^{-1} (se 10) for 3 cutting-levels (none, 5 cm and 10 cm, respectively). Deeper soil cutting annihilated emissions completely (< 1 mg CH_4 m^{-2} h^{-1}). We found temporal variability with deeper soil layers showing a CH_4 production lag phase of 2 months coinciding with strongly reduced soil conditions.

Surprisingly, planted mesocosms with 5 cm sod cutting emitted at moderated rates (18-120 mg CH_4 m^{-2} h^{-1}) often lower than unplanted soils (mean 106 mg CH_4 m^{-2} h^{-1}). Increasing salinity (50 mM chloride) also lowered methane production by 71-91% due to sulphate and chloride mediated methanogenesis reduction. This reduction effect has also been found under field conditions where peat ditches received experimental salinity levels.

Sod-cutting and salinity proved efficient management tools to cut down methane production by 71-99% in paludiculture environments. The feasibility and economic rational of these management options warrant further investigations. The effects of sod-cutting and salinity levels on plant biomass productivity, crop selection and nutrient release need to be quantified in rewetted peat soils.

Keywords: paludiculture, methane, carbon dioxide, oxidation, *Phragmites*, *Typha*, topsoil removal, salinity

SESSION 4: Economy and society

Costs and benefits are the key factors for the implementation of biomass use from wet and rewetted peatlands. The prevailing economic framework has a decisive influence on the economic viability at company level. This session covers micro-economic as well as macro-economic topics of paludiculture. Micro-economic contributions can include studies on site management, harvest, biomass processing and use. Macro-economic studies may evaluate costs and benefits of peatland use concerning the provision of ecosystem services or disservices. Studies considering, comparing and quantifying environmental impacts (i.e. greenhouse gas emissions, energy, nutrients and other flows) of peatland use are welcome. The session covers also social aspects as the individual perception of peatlands and of changes induced by rewetting.

Harvest of *Sphagnum* biomass

Wednesday, 27th September

14:30 - 14:50 | Economics of paludiculture: Sphagnum farming, reed harvesting and cattail cultivation
Sabine Wichmann

14:50 - 15:10 | A business case for reed as a renewable resource
Frank W. Croon

SESSION 4: Economy and society

15:10 - 15:30 | Biomass harvest on wet peatlands – assessment of different harvesting regimes using a labor time classification based model
Tobias Dahms

15:30 - 15:50 | Better Wetter: linking spatial adaptation to regional transitions
Ivan Mettrop

16:30 - 16:50 | Applying the concept of societal relationships with nature: insights for paludiculture and rewetting projects
Uta Berghöfer

16:50 - 17:10 | Perspectives for agriculturally used drained peat soils: comparison of the socio-economic and ecologic business environment of six European countries
Christoph Buschmann

17:10 - 17:30 | Applying systems analysis to evaluate the use of Jelutung (*Dyera* sp.) as an option for the sustainable use of peatlands in central Kalimantan
Johan Kieft (cancelled)

Economics of paludiculture: Sphagnum farming, reed harvesting and cattail cultivation

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Paludiculture relies on crops that thrive under wet conditions, and on viable utilisation avenues for the specific biomass. Peat-moss (*Sphagnum* spec.) on bog sites, as well as reed (*Phragmites australis*) and cattail (*Typha* spec.) on fen sites, are considered as promising crops for paludiculture. Long utilisation traditions as well as successful cultivation trials exist. However, only some economic data is available to estimate the prospects of those paludicultures as land use alternatives for drained peatlands.

In the case of Sphagnum farming, we compare three options of *Sphagnum* cultures. Establishing costs are lower for soil-based cultivation on former bog grassland, or cut-over bog than for water-based cultivation on floating mats. On former bog grassland, the first commercial harvest was carried out in 2016 after five years of cultivation. It allowed the first economic assessment of cultivating *Sphagnum* biomass as a high-quality growing media constituent to replace fossil peat in horticulture.

In the case of reed, we investigated the harvest with special-purpose tracked machinery for three options of energetic and material use. Harvesting reed for thatching is clearly the most profitable, followed by direct combustion, and then biogas production. In the case of cattail, we assessed the economic feasibility of *Typha* cultivation by comparing the best developed processing avenues, i.e. construction material, fuel, and fodder. Next to the ability of revenues to cover cultivation costs, other factors such as the availability of mature technology, legal restrictions, and the entitlement to agricultural subsidies influence feasibility and competitiveness of paludiculture. Thus, an adaptation of the general framework – including financial incentives for paludiculture and the remuneration of external benefits – will be required to encourage a balanced provision of ecosystem services from peatlands.

Keywords: *Phragmites australis*, *Typha*, profitability, economic incentives

A business case for reed as a renewable resource

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Reed, a potentially valuable renewable resource can be used as an energy crop for direct burning, transformed into charcoal, or 2nd generation ethanol, and is an excellent raw material for fibre board, isolation, or building materials. Setting up a viable supply chain of reed based products requires a profitable business case which independent on the continuously changing subsidies is profitable. Economic production of a reed based product requires a dependable supply of relatively large volumes, an assured demand for the product, and a developed marketing system.

The “Reed Valorization Initiative” has developed a business model, which fulfils these criteria, by harvesting and transforming 50,000 tons/year of the invasive reed from the Senegal River Delta into a bio-fuel for co-combustion with coal for the Senegalese industry. Besides the secondary benefits, (mitigating the reed invasion

problems, creating labour places, reducing CO_2 emission and saving foreign exchange), supplying baled reed-chips for co-combustion which is transported over a distance up to 250 km proved to be a profitable business proposition. The cost price per heat unit of the reed bales, is without counting the value of Carbon Credits, competitive with the cost price of imported coal delivered at the end users site.
The main costs factors of the supply chain are (i) harvesting and infield transport of the voluminous moist fresh reed and after the drying and baling, and (ii) the transport of the still relatively voluminous bales to the end user.
The harvesting and infield transport is planned to be done with an Otter reed harvester (transport capacity 50 m^3), the drying will be done on specially designed drying floors where the high temperature, low humidity, and ambient air will be blown through the chipped reed. The baling will be done with industrial balers to reach high bale densities.
Keywords: reed-bio-fuel, valorization

Biomass harvest on wet peatlands- assessment of different harvesting regimes using a labor time classification based model

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Biomass production on rewetted peatlands (paludiculture) can offer a solution for two land use challenges. It mitigates the environmental impacts of peatland drainage by rewetting while allowing to meet the increasing demand for biomass as raw material and fuel by continued agricultural use. Biomass harvest is one of the central challenges of paludiculture. Short harvesting periods require systems with high acreage performance. Acreage performance is also the most important factor on the economic viability of different paludiculture options.
Common approaches to upscale the capacity of the machinery in order to optimize acreage performance cannot be adopted for paludiculture since they do not meet the requirements set by the low bearing capacity of the soil and the high vulnerability of the turf. Suitable harvesting machinery/techniques must combine several characteristics: low ground pressure (light weight machinery with large contact area), soil preserving technique (i.e. avoidance of multiple crossing), high area efficiency, cost efficiency/ low per t biomass harvesting costs and the ability to harvest and remove biomass with the desired quality. Data on the acreage performance is rare.
The objective of this paper is to improve and complement the modelling approach of de Jong et al. (2003) by additional harvesting schemes, data on biomass productivity, the use of labor time classification, the use of stochastic simulation and the examination of the influence of specific parameters such as working with and transport capacity.
The input data for the model has been gathered by monitoring biomass harvesting for landscape conservation. Data for single and multi-stage harvesting regimes including chopped, bundled and balled biomass has been collected.
A model based estimation of the acreage performance different harvesting machinery is conducted and important variables influencing the results and which might be

starting points for further improvements will be identified.
Keywords: biomass harvest, machinery, labor time, acreage performance

Better Wetter: linking spatial adaptation to regional transitions

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The project ‚Better Wetter' concerns the testing and implementation of innovative land and water use in the province of Friesland (the Netherlands) to pave the way for spatial adaptation of the regional water system. This challenge is addressed by linking changes in water management and associated land use to the development of (monetary or other) revenues for the regional community. This approach aligns with the socio-economic transitions faced by the rural communities in question. The overarching long term goal is to redevelop the regional water system of the 'Friese boezem' as a sustainable and resilient water system. This is essentiall to meet future changes and indispensable to preserve and restore the unique ecological values of the region. Implementation of alternatives often means that existing functions and uses have to be adapted or given up. At the same time, however, new chances and opportunities open up when spatial transformation is at stake.

In Better Wetter, it is a main challenge to make people aware of these new opportunities, by the active involvement of stakeholders on the local and regional level. We want to do that by developing new functional combinations of flexible water management and ecosystem services. Further, we want to link spatial adaptation to regional transitions, by the involvement of local stakeholders, and development of revenue models -business cases- that are of interest for the region. Field pilot studies have been conducted in Friesland with cultivation of cattail and peat moss and several options for business case have been explored in our project.

Cattail for instance is used for isolation material, or processed in bio-laminates. The next step for Better Wetter is involvement of local stakeholders via business models to attract local entrepeneurs. This way, implementation of spatial adaptation on a regional scale is stimulated. www.betterwetter.nl

Keywords: Better Wetter, spatial adaptation, regional transitions, paludiculture, businesscases, *typha*, cattail, *Sphagnum* peat moss, flexible water management, ecosystem services

Applying the concept of societal relationships with nature: insights for paludiculture and rewetting projects

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In Northern Germany, the drainage of peatlands has for generations been a pre-requisite for being able to live off the land. Developing drainage infrastructure was not only a policy priority since the 18th century, but also required enormous human effort and professional expertise.

Drained peatlands are characteristic landscapes in many districts. Introducing paludiculture not only requires technical expertise, incentives, and investments to

stimulate transition. It also stirres conflict: As landscapes change from dry meadows to wet peatlands the value of the land changes, local ‚sense of place' („Heimat") is affected, and personal and professional identities are challenged.
In addition, peatlands are often associated with ‚fear' in German culture.
How can the mainstreaming of the paludiculture paradigm be supported in view of these challenges? I present the concept of societal relationships with nature (Berghöfer 2011, Görg 1999, Becker & Jahn 2005) asserting that (1) nature is not a given but is rather a result of the relations that exist among the individual, society, and the physical world; (2) the making of nature is a political and historical process; and (3) multiple alternative relationships exist whose outcomes we call "natures." It aims to explore how diversely nature is configured by different people, i.e., how they think about, relate to, and inhabit it: competing and contested natures that co-exist in the debate on conservation and rewetting of peatlands.
Based on this concept we conducted different environmental education projects, since 2013, in the region of Malchin (Mecklenburg-Western Pomerania). We created new spaces for engaging with wet peatlands, including sensual exposure to the landscape, and creative interaction with its inhabitants (animals, humans, but also historical figures and legends). I present the experience of working with adolescents, artists, and musicians in the landscape theater project called ‚Moortheater'. More than 800 people attended the two perfomances in 2016. This not only provided opportunities for a younger generation - often disconnected to their Heimat-landscapes - to emotionally, cognitively, and creatively engage with peatlands, but also stimulated wider societal debate on the pros and cons of different peatland states and associated landuses.
Keywords: societal relationships with nature, environmental education, peatland theatre

Applying systems snalysis to evaluate the use of Jelutung (*Dyera* sp.) as an option for the sustainable use of peatlands in Central Kalimantan

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Peat fire and the consequent degradation of peat land has had significant negative environmental and economic consequences at national and global levels. A green economy transition path is seen as a social economic solution to address peat degradation. Swamp agriculture better known as paludiculture is an option. However, so far little knowledge exists on the social economic viability of these options, vis a vis conventional development. This research is the first attemp to quantify the implication of a green economy based development option for a province of which 30% of the land is peat. The research using a system dynamic green economy assessment model, named Indonesia green economy model (i-gemm), to assess how three different development scenarios perform against key economic andenvironmental indicators. These scenarios are a business as usual scenario, accelerated palm oil expansion, and a green economy based on large scale paludiculture conversion. The analysis shows that BAU scenarios and the continuation of palm oil expansion lead to higher

profitability, to higher profitability, but also higher variability in revenues. At the same time it is unsustainable from a social, environmental, and also from an economic perspective when the cost of externalities are accounted for. With increased emissions, fire, and land subsidence, the BAU and palm oil expansion scenarios will continue to cause significant economic damage to the communities of Central Kalimantan and beyond, negatively affecting the health of both Indonesian populations.
Keywords: peat, paludiculture, palm oil, system dynamics modelling

Perspectives for agriculturally used drained peat soils: Comparison of the socio-economic and ecologic business environment of six European countries

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Agriculture on drained peat soils causes a multitude of problems. Such as, soil mineralisation, subsidence, and loss of biodiversity. Drained peat soils are a considerable source of greenhouse gas emissions especially in Northern and Central European countries, even if their share of the agriculturally used soils is limited.
Emission mitigation from peat soils is currently not included in the reduction commitments of the European Union (EU) climate framework. However, emissions from land use, land use change, and forestry (LULUCF) will be increasingly relevant for the EU climate targets. The EU Commission has recently published legislative proposals for the integration of LULUCF activities after 2020. Since peat soils have a high mitigation potential, they will likely be in the focus of future regulations.
We describe and compare the similarities and differences in the socio-economic and ecological business environment. Policy makers, planners, and farmers are confronted with when developing tailored suggestions for low emission land use alternatives on peat land. This lead us to carry out expert group discussions supplemented with literature reviews in different regions in Germany, The Netherlands, Denmark, Sweden, Finland, and Estonia. We discussed different land use alternatives including controlled drainage, wet grazing, paludiculture, and land abandonment. Additionally we interviewed 33 typical farmers cultivating organic soils across the study regions. The Social-Ecological System Framework (Ostrom 2009) is a well-established tool to analyse the dependencies and feedback in the management of natural resources. Based on this framework we identify and cluster important variables. Our results show that mainly the productivity of the resource systems, the economic value of land, and market incentives determine the economic efficiency of the land use alternatives. The most efficient alternative usually receives the highest level of acceptance in a given project region. Other variables are more important with respect to the implementation of alternatives, such as governance systems, property rights, heterogeneity, and conflicts among users. We point out similarities and possibilities of solution transferability between regions.
www.caos-project.eu
Keywords: peatland management, agriculture, climate protection, social-ecological system analysis

SESSION 5: Genetic and species diversity

In drained peatlands, biodiversity is substantially reduced and much of the former mire flora and fauna has disappeared. In rewetted peatlands, such species may appear again, favoured by paludiculture. Other species may suffer from machine mowing in near-natural peatlands. Understanding the physiology and genetic variation of potential plants that can be used for paludiculture, will help to support their cultivation. Selection and propagation of suitable ecotypes can improve productivity and the desired biomass characteristics. In this session, we will illuminate biodiversity effects of paludiculture, report research results on different wetland plant species, and discuss solutions for tackling challenges in implementing paludiculture by smart species selection.

Drosera and dragonfly in a Sphagnum farming field.

Wednesday, 27th September

14:30 - 14:50 | Growth response of paludicrops to fertilisation
Brian Sorrell

14:50 - 15:10 | Paludicrop plants have invasive traits - prevention is better than cure
Carla Lambertini

SESSION 5: Genetic and species diversity

15:10 - 15:30 | Will biomass oriented conservation actions only further threaten world's largest refuge of a globally threatened passerine? A case for Zvaniec fen
Viktar Fenchuk

15:30 - 15:50 | Summer or winter? Ten years of mowing in Rozwarowo marshes and Peene valley - results on vegetation and breeding birds
Franziska Tanneberger

16:30 - 16:50 | Species protection by paludiculture: *Sphagnum* cultures as surrogate habitats
Matthias Krebs

16:50 - 17:10 | Performance of *Sphagnum* species in experimental extracted peatland restoration
Edgar Karofeld

17:10 - 17:30 | Protection for optimal *Sphagnum* growth
Martha Graf

Growth response of paludicrops to fertilisation

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The success of wild wetland plants as paludiculture species depends on several factors not only associated with the environmental conditions in which plants are cultivated, but also with their intrinsic ability to acclimate to paludiculture, maintaining phenotypic traits and high production rates. Unlike food crops, which have a long history of domestication and genetic improvement, wetland plants suitable for paludiculture are sourced from natural populations and their response as crops strongly depends on the sampled genetic diversity, and ultimately on the evolutionary history of each genotype. Also, paludiculture occurs at sites with nutrient levels ranging from very low to high, and the paludicrop species should be able to grow under a range of nutrient regimes while at the same time producing a harvestable biomass.

We compared the effects of fertilisation on genotypes of four highly productive wetland species (*Phragmites australis, Arundo donax, Arundo plinii* and *Typha latifolia*) in a mesocosm setup, and analysed biomass yields as well as various ecophysiological traits and concentrations of nutrient elements in the biomass. Our aim was to identify genetically determined traits which can facilitate the cultivation of wild wetland crops in rewetted organic soils with different nutrient levels, and to identify species or genotypes capable of being used as paludiculture crops under diverse nutrient regimes.

All genotypes tested were suitable for cultivation in waterlogged conditions and yielded similar biomass in low to moderately fertilised cultures (up to 75-8-59 Kg N-P-K kg/ha/year). In highly fertilised cultures (up to 300-32-237 Kg N-P-K kg/ha/year) a Romanian genotype of *P. australis* achieved the highest aboveground biomass, together with *Typha latifolia* and *Arundo donax*. *A. donax* is considered the most productive herbaceous crop in Europe suitable for bioenergy. We found that *P. australis* and *T. latifolia* could potentially be equally productive as *A. donax* under some conditions. However, unlike *A. donax* which is known to be one single sterile genotype which has spread by vegetative propagation throughout Mediterranean Europe, *P. australis* and *T. latifolia* populations are cosmopolitan in Europe and have greater genetic diversity. Their diversity may play a pivotal role for the establishment of paludiculture as a profitable and sustainable form of agriculture.

Keywords: nutrient uptake, fertilisation, genotypes, biomass production

Paludicrop plants have invasive traits – prevention is better than cure

Lambertini, Carla[1) 2)]; Zanetti, Federica[1)]; Zegada-Lizarazu, Walter[1)]; Monti, Andrea[1)]; Eller, Franziska[2)]; Sorrell, Brian[2)]; Brix, Hans[2)]

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The success of paludiculture as a sustainable source of bioenergy does not depend only on the technical possibility of cultivating wetlands and producing energy from

wetland plants, but also on the ability of wetland plants to acclimate to paludiculture, maintain high production rates, and ecosystem services, without damaging the environment. Unlike food crops, which have a long history of domestication and genetic improvement, paludiculture plants are sourced from natural populations and the choice of crop species, the selection of suitable genotypes and the movement of propagules within and among ranges have an effect on an ecosystems ecology.
Tall wetland grasses, like *Phragmites*, *Typha*, and *Arundo* species, are candidates for bioenergy crops because of their high yields of lignocellulosic biomass, wide ecological tolerance (including both flooding and temporary drought), rapid establishment, high resource-use efficiency, and high tolerance to mowing disturbance in general. These traits have double-edged effects: they provide desirable ecosystem services, like high CO_2 assimilation rates from the atmosphere and water cleaning. However, this makes these species extremely competitive and highly invasive. The lesson is learnt from North America where *Phragmites australis*, *Phalaris arundinacea*, and *Typha* spp. are invasive. *Arundo donax* is shortlisted among the 10 most invasive species in the world. All these plants are cosmopolitan polyploid species complexes with a complicated population structure, due to outcrossing, hybridisation, introgression, polyploidisation, and long-distance dispersal of pollen and seeds (except sterile *Arundo donax*). They are also keystone species in aquatic ecosystems. Breeding and moving propagules of these "genomically plastic" plants facilitate the introduction of genotypes and alleles in the wild populations, and this has a strong impact on the evolution of wetlands at the global scale. Genetic and genomic traits, inheritance and dispersal patterns of paludicrops, require scientific attention because they play a crucial role in the sustainability of paludiculture and its renewable resources.
Keywords: wetland plants, genetic traits, hybridisation, polyploidy, dispersal, wild, breeding

Will biomass oriented conservation actions only further threaten world's largest refuge of a globally threatened passerine? A case for Zvaniec fen mire (Belarus), the Aquatic warbler and reed winter burning and mowing.

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Zvaniec mire, located in the southern Belarus, is the world's largest breeding site of globally threatened Aquatic warbler *Acrocephalus paludicola*. The site supports 2,149-4,459 vocalizing males, or 72-80% of Belarusian population of the species. One of every three Aquatic warblers of the world breeds here. The total area of Zvaniec IBA is 16,230 ha, of which 10,460 are protected by landscape reserve of national significance "Zvaviec". The results of monitoring work showed that as of 2015 Aquatic warbler occupied only 4,660 ha and the area suitable for the species was decreasing due to overgrowth of open fen mire with bushes in the northern part and reeds in the southern part.
National action plan for conservation of the Aquatic warbler lists actions is aimed at preventing overgrowth of open fen mires by bushes and reeds, through active

conservation measures as of critical significance. Such measures are listed as priority in Zvaniec reserve Site management plan.
With regard to a huge area to be managed and absence of sustainable financing mechanisms (i.e. agri-environmentals schemes), a number of conservation project were initiated and implemented at Zvaniec to identify and pilot cheap and self-supporting habitat management techniques. Among them – winter burning of reeds and winter mowing of reeds with biomass collection and subsequent pelleting. Biomass briquetting facility and set of mowing and harvesting and processing equipment are being purchased to enable winter reed mowing at Zvaniec. Pilot reed burning at Zvaniec was implemented in 2015 and then consequently at Sporava mire (2017).
At the same time, winter burning and mowing of reedbeds, while being indeed cost-effective and potentially self-sustaining, may come into contradiction with conservation aims for Zvaniec, which are to stop and reverse expansion of reeds. A number of studies show that winter mowing of reeds, as it was traditionally done in Europe for gathering construction material, leads to increasing reed density and reed biomass. Contemporary conservation management guidelines recommend such actions to support reed beds development (i.e. for conservation of such species as bittern).
Given the immense significance of Zvaniec for conservation of the globally threatened Aquatic warbler, a precautionary approach should to be taken when choosing habitat conservation measures. As some of them may even further exacerbate the problem of reed expansion.
Keywords: fen mire, reeds, Aquatic warbler, winter burning

Summer or winter? Ten years of mowing in Rozwarowo Marshes and Peene Valley - results on vegetation and breeding birds

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We present results from two ten-year-studies on mowing effects conducted in near-natural peatlands close to Odra Lagoon, NW-Poland and NE-Germany. Both peatlands hold important biodiversity values (flora and fauna) and in both sites, mowing is related to agricultural funding schemes. We have studied plant communities, vegetation structure and bird populations in both sites since 2006. We present outcomes in the light of mowing, hydrological regime and nutrient conditions. Rozwarowo Marshes is a Natura 2000 site and located 15 km from the Baltic Sea between Kamień Pomorski and Wolin (NW-Poland). Water levels are largely artificially managed by three landowners managing the site, mainly for winter reed cutting. The site is famous for rare mire species such as *Myrica gale* and *Carex pulicaris*, but also halophytes and especially for the globally threatened Aquatic

Warbler (*Acrocephalus paludicola*). Rozwarowo Marshes are the last stronghold of its "Pomeranian population". It is assumed that winter reed cutting can maintain plant species diversity and Aquatic Warbler habitats as long as trophic conditions remain stable. In recent years, very nutrient-rich water affects the site. Since 2016, a conservation project implements urgent measures to reduce nutrient loads.
The Lower Peene Valley is a large peatland east of the city of Anklam. Large parts are Natura 2000 sites and nature reserve. Summer mowing for conservation has been reintroduced in 2005 on 150 ha within a Polish-German LIFE project. At that time, the main focus was to restore habitat of the globally threatened Aquatic Warbler (*Acrocephalus paludicola*). Summer mowing is now continued using agricultural payments. Floristic composition indicates a slow change from species-poor, dense reeds to more open and species-rich sedge-reed vegetation. Summer mowing can create suitable habitat conditions for waders such as Redshank (*Tringa totanus*) and Lapwing (*Vanellus vanellus*). Using biomass from conservation mowing in remote peatland areas remains a challenge.
Keywords: biomass, vegetation structure, threatened species, decomposition

Species protection by paludiculture: *Sphagnum* cultures as surrogate habitats

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Mires harbour some of the most vulnerable and endangered communities of flora and fauna in western and central Europe due to habitat loss. In Germany, 99% of the 1.4 Mha of peatlands have been drained for land use and only 1% is still in a natural state. The role of surrogate habitats increases to maintain species diversity. In our study, we analysed whether paludicultures on degraded bogs (Sphagnum farming) could constitute a valuable surrogate habitat in particular for rare and threatened bog species. In this respect, we studied the biodiversity succession in two Sphagnum farming sites, in north western Germany, over ten years. We focused on diversity of vascular plant and moss species. Moreover, the highly diverse arthropod groups of spiders and harvestmen were used as bioindicators to track changes in species assemblages over the first six years at the Sphagnum farming site on former bog grassland in comparison to its surroundings.
Many rare plant bog species were observed in the established *Sphagnum* lawns. With regard to succession the spider communities changed rapidly from assemblages dominated by disturbance specialists (pioneer species) in the first year after installation to diverse assemblages with large proportions of peatland generalists in the following years.
Our study demonstrated the additional benefits of Sphagnum farming for plant and animal diversity. In our paper we discuss parameters influencing the biodiversity in such paludicultures and develop recommendations for management too.
Keywords: biodiversity, peatland species, Sphagnum farming

Performance of *Sphagnum* species in experimental extracted peatland restoration

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As the legacy from long time peat production there are ca 9400 ha of abandoned extracted peatlands in Estonia, and the area will increase in coming decades as the current production sites on ca 20.3 thousand ha will be closed. Because of their large area, deep drainage, lack of viable propagules, and unfavourable environmental conditions the spontaneous re-vegetation of milled extracted peatlands is a very slow and scattered process. In spring 2012 we initiated an experimental study to test the suitability of "The moss layer transfer method" in Northern European conditions and to find out the suitability of different *Sphagnum* species for use in restoration. We spread *Sphagnum* fragments from the donor site in a natural bog to extracted peatland with stripped surficial loose peat layer in ratio 1:10 and 1:15 on two areas with different water table depth.

By the end of the 5th growing season since restoration the total plant cover has reached up to 80 % (mean 67.6%). The majority of the plant cover is formed by *Sphagnum* mosses, being in mean 63.7 %. From six *Sphagnum* species recorded in donor site only *S. tenellum* was not found on restoration areas. From *Sphagnum* species biggest mean cover had *S. fuscum* and *S. rubellum*. Latter species shows also biggest cover increase in years. The length increment (mm yr^{-1}) of three main bog species - *S. fuscum, S. rubellum,* and *S. magellanicum* on restored peatland was smaller than on natural bogs, especially on area with lower water table. Decreased increment is compensated by the increased weight of *Sphagnum* capitulae on restored area, especially of *S. rubellum* and *S. magellanicum.*

The role of surface preparation, water table depth and spreading density of *Sphagnum* fragments on the changes in cover and growth of *Sphagnum* mosses and suitability of different species for restoration will be analysed.

Keywords: restoration of extracted peatlands, *Sphagnum*

Protection for optimal *Sphagnum* growth

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The cultivation of peat moss is currently the only paludiculture option available for bogs. The cultivated peat moss (*Sphagnum* spp.) would provide a sustainable substitution for white peat in peat products, such as growing media. This study analyses the growth of complete peat moss fragments and micropropagated peat moss fragments of *Sphagnum magellanicum* Brid. and *S. capillifolium* (Ehrh.) Hedwig under different cover conditions, such as geotextile, straw, and without a cover. The experimental design was set up on a milled peatland in Lower Saxony, NW Germany. A complete randomized block design was set up with four repetitions of 18 different applications under a shading tunnel as well as in an outdoor area. The growth was assessed on the basis of mean heights, coverage, and number of new shoots. An analysis of variance shows, that especially the straw coverage and

conditions in the tunnel had a positive effect on both species growth and percentage cover, *S. capillifolium* shows a higher production of new shoots. However, significant results were only obtained for the data of the complete peat moss fragments, since the micropropagated BeadaGelTM barely grew during the time of observation.
Keywords: straw mulch, geotextile, *Sphagnum* fragments, micropropagated moss

SESSION 6: Quality and quantity of water and nutrients

Wet and rewetted peatlands have regulating influence on nutrient dynamics in ground and surface waters, both as sinks and sources. Besides carbon and biodiversity aspects, nutrient cycling can be a major driver for restoring degraded peatlands. Data on nutrient input and output of wetland systems, but also the processes behind nutrient dynamics will be presented in this session. Presentations focus e.g. on filter potentials of paludicultures, redox-dependent mechanisms for solute adsorption and retention (P) as well as on conversion of substances by nitrification/denitrification (N) and uptake by biomass (paludiculture).

Irrigation of a Sphagnum farming field with ditch water

Thursday, 28th September

09:40 - 10:00 | Nutrient recycling in rewetted peatlands used for paludiculture
Jeroen Geurts

10:00 - 10:20 | The influence of nitrogen input on biomass yield and nutrient sequestration in rewetted peatlands
Renske Vroom

SESSION 6: Quality and quantity of water and nutrients

10:20 - 10:40 | Nutrient preferences and limitations of paludicrops: insights from the photosynthesis-nitrogen relationship
Brian Sorrell

10:40 - 11:00 | Managing nutrient and carbon release from inundated peatlands
Domonik Zak

11:40 - 12:00 | Azolla farming on rewetted peat soils
Alfons Smolders

12:00 - 12:20 | Sphagnum farming initiatives in Canada: an overview
Sandrine Hugron

12:20 - 12:40 | The water balance of a Sphagnum farming site in Northwest Germany
Kristina Brust

12:40 - 13:00 | Sphagnum farming in a eutrophic world: the importance of optimal nutrient stoichiometry
Ralph Temmink

Nutrient recycling in rewetted peatlands used for paludiculture

Geurts, Jeroen[1]; Fritz, Christian[1) 4)]; Lambertini, Carla[2) 5)]; Eller, Franziska[2)]; Sorrell, Brian[2)]; Oehmke, Claudia[3)]; Grootjans, Ab[1) 4)]; Brix, Hans[2)]; Joosten, Hans[3)]; Lamers, Leon[1)]

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Climate change and sea level rise force us to have more water storage areas on former agricultural soils, what has lead to an enormous nutrient mobilization with tremendous effects on surface water quality. Top soil removal is expensive and often undesirable, so paludiculture with fast-growing Paludicrops (e.g. cattail, reed, willow) could be the solution. Rewetting of peatlands for paludiculture is a sustainable form of climate smart agriculture, which can provide significant biomass yields while restoring several important ecosystem functions.

In this talk we present an overview of carbon and nutrient sequestration in the aboveground biomass of Paludicrops in field sites of the Cinderella project (D, DK, NL, S) in relation to soil conditions. We found that Paludicrops sequester aboveground carbon (C; 4-14 ton/ha), nitrogen (N; 150-600 kg/ha), phosphorus (P; 20-80 kg/ha), and potassium (K; 100-400 kg/ha) in stands older than 5 years. Surprisingly, young stands of *Typha latifolia* accumulated 10 tons of dry matter in 2 cuts in the 2nd season without extra nutrient input, which equals the yield of drained and fertilized grasslands. Total yield was independent of the date of the first cut (May, July, August, September). Crude protein yield equaled 1275 kg/ha (May harvest).

The N:P ratio of *Typha latifolia* biomass (5-8) suggested N limitation and resulted in high P-uptake (median 27 kg/ha) compared to *Phragmites australis* (N:P 10-12 & median 14 kg P/ha). We only found a weak relationship between soil phosphorus (Olsen-P upper 20 cm) and plant phosphorus. Soil nitrogen available to plants and soil C/N ratio were weak indicators for N sequestration.

Paludicrops on rewetted peatlands hold a large potential to combine high yields, water purification, CO_2 emission reduction, and peat preservation based on this field survey. In that way, farms can efficiently use N and P from their effluent and comply more economically with environmental legislation concerning nutrient losses.

Keywords: nutrient sequestration, field gradient, soil conditions, paludiculture

The influence of nitrogen input on biomass yield and nutrient sequestration in rewetted peatlands

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Restoration of degraded peatlands through rewetting poses challenges concerning nutrient dynamics. As rewetting leads to nutrient mobilisation and subsequent water

quality issues, nutrient removal from these systems is imperative. Paludiculture, crop cultivation on rewetted peat soils, can serve as a means for this. However, paludiculture crops are often nitrogen (N) limited as a result of increased denitrification in wet anaerobic soils. Thus, using N-rich water, for example farm run-off, could promote nutrient removal from rewetted peat soils. To investigate this, we studied the influence of N addition on biomass production and nutrient sequestration by *Typha latifolia* (broadleaf cattail) and *Phragmites australis* (common reed).
A 90-day mesocosm study was carried out using two peat soils with different characteristics (neutral and low pH). Different N loads (0, 50, 150 and 450 kg ha^{-1} yr^{-1}) were applied to soils with or without vegetation. Surface water level was kept at 5 cm above the soil and temperature at 15 – 18 °C.
We found that N addition positively influenced biomass production and nutrient uptake of both *T. latifolia* and *P. australis*, with *T. latifolia* showing the most pronounced response. Biomass yield was higher in neutral soil compared to acid soil. Added nitrogen was taken up by the vegetation to a large extent, whereas bare soils showed N accumulation in pore water and surface water and high losses through denitrification (80%). Phosphorus (P) was efficiently taken up by the vegetation, preventing mobilization to the surface water. P mobilisation decreased with increasing N loads.
We showed that N addition promotes biomass yield as well as nutrient sequestration in both *T. latifolia* and *P. australis*. Both species show a high potential for N and P removal after peatland rewetting. Crop cultivation on rewetted peatlands is beneficial for water quality and can provide economic benefits through biomass production as well as compliance to environmental legislation.
Keywords: peatland restoration, paludiculture, water quality, productivity

Nutrient preferences and limitations of paludicrops: insights from the photosynthesis-nitrogen relationship

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The preferences of various candidate plants for different nutrient regimes and how they manage limiting nutrients are important considerations for achieving optimal plant survival and biomass production in paludiculture. Nitrogen (N) is the nutrient that will most commonly limit biomass production in rewetted environments, where paludiculture is performed. It limits growth and productivity of fast-growing wetland plants, primarily due to its investment in photosynthetic enzymes, especially Rubisco, in leaves. The extent to which N limits photosynthetic activity and growth can be assessed from the leaf photosynthesis-N relationship, an important tool in comparing plant nutrient responses. We compared photosynthesis-N relationships and growth responses to N between three important wetland plants with potential for paludiculture in Europe: *Phragmites australis*, *Typha latifolia*, and *Arundo donax*. The comparisons were made across a range of availability of both N and phosphorus (P), which can also limit plant production in wetland environments under some conditions. Regressions of photosynthesis against N were significant for all three

species, but slopes of regressions against N differed and indicated different nutrient preferences. *T. latifolia* had the steepest slope of the photosynthesis-N relationship and greatest increase in growth rate with increasing N. At very high N supply, photosynthesis and growth became significantly P-limited, suggesting that high concentrations of both nutrients are important for maximum productivity. Responses of the other two species to N were less spectacular than that of *T. latifolia*, and both *A. donax* and *P. australis* performed better at low N supply than *T. latifolia*. This data contributes to determining optimal growth conditions for paludiculture crops; demonstrating the high nutrient requirements of *T. latifolia* and better performance of the other species, especially *P. australis*, in less fertile soils.
Keywords: paludicrops, nutrients, productivity

Managing nutrient and carbon release from inundated peatlands

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An important strategy for the mitigation of nutrient pollution and climate change is the restoration of degraded minerotrophic peatlands. However, full rehabilitation of the mitigation capabilities may be retarded for several decades (or centuries), in particular if the upper soil layers are highly degraded. The knowledge of the processes controlling matter release and their relative importance over time is essential for securing the best restoration management. While this remains a theoretical approach, it can be essential to support water authorities and landscape managers deliver sound environmental decision making. Additionally, other aspects, such as economic and social issues may vary greatly, even on a local scale, consequently restoration measures must be implemented as one element within a holistic and systemic management plan. Based on existing knowledge, and cognizant of the realities of financial constraints on restoration projects, harvesting of helophytes or hydrophytes to extract nutrients and labile organic carbon from inundated peatlands is recommended. This measure can be useful to break the internal eutrophication, elevated methane emissions, and to accelerate the re-establishment of the nutrient and carbon sink function. Such measures might be particulary meaningful if costs can be reduced or even compensated by a commercial use of the harvested material. We provide empirical evidence, based on field and lab experiments, on uptake and release of nutrients and different carbon forms on the implications and effectiveness of different restoration strategies such as biomass usage from rewetted peatlands, which is sometimes termed “paludiculture”.
Keywords: helophytes, climate change mitigation, rewetting, paludiculture, water pollution, wetlands

Azolla farming on rewetted peat soils

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As a result of intensive fertilisation, agricultural lands show excessive accumulation of phosphorus (P) in their topsoils. Unlike nitrogen (N), P is strongly bound, particularly in clay- and organic soils. The rewetting of P-rich soils inevitably results in immense eutrophication of the overlaying water and of downstream areas. The P legacy of ex-arable lands and former pastures places a significant constraint on rewetting programs aiming at water storage, development of hydrological buffer zones, abatement of land subsidence, and wetland restoration for recreation and biodiversity. Azolla ranks among the fastest growing plants on Earth and is capable of reaching a very high biomass produc-tion under P-rich conditions, due to its symbiosis with cyanobacteria (including Nostoc azollae) preventing N limitation by their dinitrogen (N_2) fixation. As floating mats of Azolla efficiently block oxygen diffusion into the water layer, the anaerobic mobilisation of P from nutrient-rich soils, linked to microbial iron reduction, is strongly enhanced. Already existing applications with Azolla biomass include its use as a green manure, as an animal feed and for the production of bio-gas. Furthermore, it is widely being applied as a phytoremediation tool for contaminated surface waters and waste waters. In the Netherlands we started a research project in which we study the prospects and prerequisites for the use of Azolla as a bio-engineer and wet crop on former agricultural lands that either have become too wet to be drained due to land subsidence, or are being rewetted for the suite of societal services. Our target is to initiate and optimize the full chain of Azolla growth and harvest, P extraction, reduction of greenhouse gas emissions, and the production of proteins and other products for commercial use, while minimising greenhouse gas emissions. We use an interdisciplinary approach, including biogeochemistry, hydrology, plant physiology, organic chemistry and life cycle analysis.

Keywords: Azolla, rewetting, P recycling

Sphagnum farming initiatives in Canada: an overview.

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Since 2013, two Sphagnum farms with automated irrigation have been implemented in Eastern Canada, in order to produce *Sphagnum* fibres on a cyclic and renewable basis.

In both sites, two targets for water table (-10 cm and -20 cm), different positions of canals as well as subsurface irrigation drains were tested. The productivity of the different *Sphagnum* species introduced, the hydrology of the sites, the carbon exchanges in relation to the water level, and the design of the farming basins have been monitored. After three and four growing seasons, the following conclusions were drawn:

1) *Sphagnum* productivity in irrigated basins is higher than in unmanaged basins: a water table maintained around -10 cm tripled the biomass accumulation whereas when maintained around -20 cm the biomass accumulation doubled in comparison to unmanaged *Sphagnum* culture basins,

2) maintaining a stable water table (range below 15 cm) resulted in higher CO_2 uptakes by the moss layer, and

3) hydrology of drainage basins can be affected by ground water inputs outside the experimental area (i.e. from adjacent unrestored trenches), and by the position of the drainage canals in the landscape. Results from other small-scale trials for optimizing yields and harvesting of biomass will also be presented.

This presentation will summarise the research of several teams (vegetation, hydrology, and carbon) and will present a very brief overview of each topics.

Keywords: biomass production, controlled irrigation, rewetted peatland, moss layer transfer technique

The water balance of a Sphagnum farming site in Northwest Germany

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Sphagnum farming is the commercial cultivation of *Sphagnum* (peat moss) biomass, and provides a sustainable wet land use alternative for drained and degraded peatlands. On a former bog grassland within the 'Hankhauser Moor', in Northwest Germany (Lower-Saxony, N 53°15.80' E 08°16.05'), a 4 ha Sphagnum farming site was installed in 2011 and equipped with an irrigation system to control water flow. The water balance components of the site (precipitation, inflow, evapotranspiration, seepage, outflow, and stored water) were determined by combining measurements and modelling.

Water losses were mainly attributable to evapotranspiration, horizontal (to neighbouring drained sites) and, to a small extent, vertical discharge to the aquifer. Also because of these discharge losses precipitation cannot ensure the permanently wet conditions necessary for optimal *Sphagnum* growth. During summer, when evapotranspiration exceeds precipitation, Sphagnum farming requires irrigation to prevent water levels from falling too deep. In times of precipitation surplus, on the other hand, the site also needs an overflow facility to avoid flooding and consequent growth reduction of the peat mosses.

In our paper, we illustrate the water management of the study site and present the water balance components of the Sphagnum farming site for the hydrological year 2013. Finally, we identify the irrigation volume necessary to keep the water table of the site close below the *Sphagnum* surface throughout the year.

Keywords: Sphagnum farming, irrigation, rewetted/wet peatland, water management, paludiculture

Sphagnum farming in a eutrophic world: the importance of optimal nutrient stochiometry

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1. Agriculture on rewetted peatlands (paludiculture) provides a sustainable alternative to drainage-based agriculture. One form of paludiculture is the cultivation of *Sphagnum* moss, which can be used as a raw material for horticultural growing media. Under natural conditions, most *Sphagnum* mosses eligible for paludiculture typically predominate only in nutrient-poor wetland habitats. It is unknown, however, how the prevailing high nutrient levels in agricultural peatlands interfere with optimal *Sphagnum* production.

2. We therefore studied the effect of enriched nutrient conditions remaining even after top soil removal and further caused by external supply of nutrient-rich irrigation water and (generally) high inputs of atmospheric nitrogen to habitat biogeochemistry, biomass production and nutrient stoichiometry of in 2011 introduced *Sphagnum palustre* and *S. papillosum* in a rewetted peatland, which was formerly in intensive agricultural use.

3. Airborne N was responsible for the major supply of N. Phosphorus (P) and potassium (K) were mainly supplied by irrigation water. The prevailing high nutrient levels (P and K) are a result of nutrient-rich irrigation water from the surroundings. Peat porewater (10 cm depth) CO_2 concentrations were high, bicarbonate concentrations low, and the pH was around 4.2.

4. Provided that moisture supply is sufficient and dominance of fast-growing, larger graminoids suppressed (in order to avoid outshading of *Sphagnum* mosses), strikingly high biomass yields of 6.7 and 6.5 ton DW ha^{-1} yr^{-1} (*S. palustre* or *S. papillosum* [including *S. fallax* biomass], respectively) were obtained despite high N supply and biomass N concentrations. Even though high P and K supply and uptake, N:P and N:K ratios in the *Sphagnum* capitula were still low. *Sphagnum* mosses achieved high nutrient sequestration rates from May 2013 to May 2014 dominated by nitrogen (34 kg N) and a N:P of 3.5 and N:K of 2, which shows that the site acted as an active nutrient sink. We will also present the first results of nutrient fluxes at a newly (2016) established Sphagnum farming site with moss growth at an early stage.

5. In conclusion, Sphagnum farming is well able to thrive under high N input provided that there is a simultaneous high input of P and K from irrigation water, which facilitates high production rates. Due to the lack of suitable, nutrient poor sites, it was therefore strongly recommended to remove the topsoil prior to start growing *Sphagnum* mosses. In addition, bicarbonate concentrations have to stay sufficiently low to ensure a low pH, CO_2 supply from the peat soil should be sufficiently high to prevent C limitation, and graminoids should be mown regularly.

Keywords: peatland, nutrient supply, paludiculture, biomass, stoichiometry, nitrogen deposition, rewetting, agriculture

SESSION 7: Legal and policy framework| incentives & constraints

The implementation of paludiculture may be fostered or hampered by the policy framework and legal regulations. The eligibility for agricultural subsidies, e.g. provided by the EU Common Agricultural Policy, plays a fundamental role for implementing paludicultures in the EU. Incentives for rewetting and/or for establishing adapted wetland plants may improve the willingness to introduce paludicultures on formerly drained peatlands. Payments for the provision of ecosystem services such as carbon storage, nutrient removal or water retention can support the profitability and competiveness of paludiculture. We encourage presentations on the following aspects: analyses on incentives and constrains in different countries; How can the legal and policy framework account for the provision of peatland ecosystem services and disservices? What are the pre-requisites for ensuring the acceptance of incentives in policy and practice? Which (national) solutions may serve as best practise examples to overcome constraints and to support paludiculture or the utilisation of wetland biomass?

Rewetted fen peatlands in the Landgraben, Mecklenburg-Western Pomerania

SESSION 7: Legal and policy framework| incentives & constraints

Thursday, 28th September

14:30 - 14:50 | Implementing paludiculture - How can we avoid land-use conflicts?
Christian Schröder

14:50 - 15:10 | Impacts of the EU Common Agricultural Policy and the EU climate policy on the mitigation of greenhouse gas emissions from drained peat soils
Bernhard Osterburg

15:10 - 15:30 | Promoting paludiculture in the next Common Agriculture Policy framework
Annette Freibauer

15:30 - 15:50 | Is Europe ready for paludiculture? Implications of the EU regulatory environment
Jan Peters

Implementing paludiculture - How we can avoid land-use conflicts?

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Mecklenburg-Western Pomerania has a peatland area of 291,361 ha (12.5 % of the country). 165,880 ha (57 %) are used for agriculture, 20,531 ha as arable land, and 143,998 ha as permanent grassland (ML M-V 2017). The utilisation is associated with high greenhouse gas emissions of 4.5 million tons of CO_2-eq a^{-1} (LU M-V 2009). To reduce these greenhouse gas emissions, the introduction of paludiculture is necessary. Paludiculture requires water levels that do not drop by more than 20 cm below ground even in summer. All paludicultures has to be permanent. By increasing water levels and adapting the land use, up to 3 million tons CO_2-eq. could be avoided annually (ML M-V 2017).

The implementation of paludiculture can lead to new land-use conflicts. For example, the creation of reed fields could lead to a loss of traditionally used grassland which has still a value for nature conservation. Thus, a multidisciplinary working group was formed to develop conceptual guidelines for planning and implementing paludiculture.

The paludicultures were differentiated into 'crop paludicultures', which are established by purpose (planting, seeding, or adjusting the management to establish target vegetation) and 'wet meadow paludicultures', which emerge from permanent grassland just by a controlled raising of the water level. Considering existing laws and frameworks of land use planning, areas suitable for the implementation of 'crop paludicultures' and 'wet meadow paludicultures' were distinguished.

Almost 18 % of the agricultural used peatland (28,827 ha) is protected in any matter. On these areas only 'wet meadow paludiculture' can be established. At 52 % (85,468 ha) of the agricultural used peatlands there is no planning or legal restrictions. 'Crop paludicultures' such as Common Reed (*Phragmites australis*), Cattail (*Typha* spec.), sweet grasses like Reed Canary Grass (*Phalaris arundinacea*), Black Alders (*Alnus glutinosa*), or other wet-tolerant permanent crops can be cultivated there. On 30 % of the utilised peatland area (49,929 ha) additional planning guidelines have to be considered. This may lead to restrictions for establishing 'crop paludicultures'.

The developed conceptual guidelines make clear what kind of paludiculture could be established where in Mecklenburg-Western Pomerania. We highly recommend to adjust these guidelines for every region to avoid land use conflicts between agriculture and nature conservation.

Keywords: crop paludiculture, wet meadow paludiculture, land-use conflicts, peatland, greenhouse gas emissions

Impacts of the EU Common Agricultural Policy and the EU climate policy on the mitigation of greenhouse gas emissions from drained peat soils

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Due to high greenhouse gas (GHG) emissions from drained peat soils, rewetting of peatlands and the production of wetland biomass (paludiculture) have a large potential for climate mitigation. However, in the given legal context wetland restoration faces many disincentives and constraints resulting from EU policies for agriculture and climate. Without reforming and further developing relevant EU policies, this potential might remain under-utilised.

The EU Common Agricultural Policy (CAP) is favouring forms of agricultural land use depending on drainage, while rewetting and the conversion towards wetland biomass production is hampered. Plants like reed, sedges, rush or cattail are not eligible for direct payments of the CAP's 1st pillar and thus excluded from this area-related support. When rewetting grassland, vegetation pattern change and patches of non-eligible plants might emerge. This causes conflicts with GAEC requirements (good agricultural and environmental condition) compulsory for land eligible for payments in the CAP. In addition, if grassland is converted to wetland or paludiculture, this may be accounted for as a loss of grassland, and compensations might be necessary. In the EU climate policy, there is a slow process of stepwise integration of land-use related GHG sinks and emissions. Until 2020, emissions from drained peatlands are not accounted for the EU emission targets. From 2021 onward, the source group land-use, land-use change and forestry (LULUCF) will form a third pillar of the EU climate policy. Sinks and emissions are accounted against different reference levels, and overall the new LULUCF pillar should be at least neutral ("no-debit") at member state level. A limited number of GHG mitigation credits can be accounted for towards national mitigation targets in other sectors. Doubts remain whether these provisions will sufficiently incentivise climate actions for restoring peatlands in the next decade.

Keywords: peatland restoration, greenhouse gas mitigation, Common Agricultural Policy, integration of LULUCF

Promoting paludiculture in the next Common Agricultural Policy framework

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The European Common Agricultural Policy (CAP) sets important financial and administrative boundary conditions for paludiculture and for the protection and rewetting of organic soils. Current instruments and solutions for promoting paludiculture at regional level have been analysed in the frame of the EU-ERANET project CAOS - Climate Smart Agriculture on Organic Soils.

The CAP direct payments do not differentiate between mineral and organic soils, cropland, and grassland. The current rules for cross compliance do not account for

the ongoing peat mineralization and associated carbon loss and water pollution from drained organic soils. They do not produce any incentive for taking the challenge of rewetting and moving to paludiculture. The next CAP framework will need to reconsider the standards of Good Agricultural and Environmental Conditions. Likewise, the respective Codes of Good Agricultural Practice could be adapted.
Some Member States and regions have developed promising instruments under the 2nd Pillar, which may be adapted to conditions elsewhere. Promising examples are highlighted and the potential for a wider application is discussed. It seems essential for success (1) to show clear mid-term perspectives, in particular a pro-active political framework, (2) to combine instruments for investment with instruments for management, (3) to have strong supportive activities of knowledge transfer and demonstration, and (4) to support innovation through the value chain for paludiculture products. Promoting paludiculture goes beyond CAP. Consistent policies are needed, best based on national or regional peatland conservation and rewetting strategies. Soil and water protection, water legislation and rural development are key players for successfully scaling up paludiculture. | https://www.thuenen.de/de/ak/projekte/caos/
Keywords: Common Agricultural Policy

Is Europe ready for paludiculture? – Implications of the EU regulatory environment

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Peatlands are Europe's largest terrestrial carbon storage and habitat for unique biodiversity, but conservation, restoration, and adapted utilisation across Europe fall short of reaching EU's biodiversity and climate targets. Their management -including paludiculture- is mainly influenced by EU regulations and policies in the fields of environment, agriculture, and regional development. The EU's Common Agricultural Policy (CAP) is arguably the single most important policy instrument in the context of peatland management, as the majority of peatlands across the EU are drained for agriculture. EU agricultural subsidies are the main driver of peatland management and degradation. Incentives for large scale restoration or adapted farming like paludiculture outside of protected areas are missing as the sectoral policy approach hinders compliance with climate and biodiversity targets to receive payments. Good agricultural practice and cross-compliance obligations exist, but references to protection needs of organic soils are few; considerations of climate change issues are vague. We conducted an integrative survey giving a comprehensive overview of related EU legislation and funding mechanisms while carving out the positive and negative effects on peatlands as well as paludiculture with special emphasis on the sectors agriculture, climate, renewable energy, nature conservation, structural, regional, and rural development policies. Challenges and obstacles for paludiculture were assessed. To minimise contradicting consequences between sectors and fill regulative gaps we drafted corresponding policy options.
Keywords: EU legislation, Common Agricultural Policy, funding mechanisms

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Paludiculture - climate smart land use on peatland

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Conventional peatland utilisation requires drainage, which results in enormous emissions of greenhouse gases and nutrients. Almost 25 % of worldwide carbon dioxide (CO_2) emissions from the LULUCF (land use, land use change and forestry) sector are caused by drained peatlands. Peatland degradation is also responsible for ongoing land subsidence, with annual height losses of 1–2 cm in the temperate zone and about 5 cm in the tropics. Rewetting of drained peatlands is essential to reduce emissions and peat degradation, but rewetting has hitherto resulted in the loss of productive land. Here we present the basic principles of paludiculture ('palus'– latin for 'swamp'), a new land use concept involving the sustainable use of wet and rewetted peatlands for agriculture and forestry, i.e. combining production with soil conservation and possibly even renewed peat growth.

Paludiculture

- is the agricultural or silvicultural use of wet and rewetted peatlands. Paludiculture uses spontaneously grown or cultivated biomass from wet peatlands under conditions in which the peat is conserved or even newly formed.
- differs fundamentally from drainage-based conventional peatland use, which leads to huge emissions of greenhouse gases and nutrients and eventually destroys its own production base through peat soil degradation.
- allows the re-establishment and maintenance of ecosystem services of wet peatlands such as carbon sequestration and storage, water and nutrient retention, as well as local climate cooling and habitat provision for rare species.
- implies an agricultural paradigm shift. Instead of draining them, peatlands are used under peat-conserving permanently wet conditions. Deeply drained and highly degraded peatlands have the greatest need for action from an environmental point of view, and provide the largest land potential. The implementation of paludiculture is the best choice for degraded peatlands worldwide and various plants can be cultivated profitably.
- cultivates crops that do not require regular tillage or other major soil works. Annual or short living crops can be cultivated only within a cover of permanent crops (e.g. sundew in peatmoss). Paludiculture also excludes plants, of which the belowground parts are harvested (e.g. *Acorus calamus* rhizomes or *Eleocharis dulcis* corms). An overview of potential paludiculture plants is given in the Database of Potential Paludiculture Plants (DPPP).
- is also a land use alternative for still natural peatlands particular in regions where the increasing demand for productive land drives drainage. Pristine peatlands should

best be protected entirely because of the valuable ecosystem services they provide. If, however, land use is unavoidable, paludiculture should always be given preference over drainage-based land use.
- should in its implementation always consider existing nature conservation values. Establishment of new reedbeds should, for example, be avoided on wet meadows with high peatland associated nature conservation values and rather focus on sites without existing values.
Paludiculture is the only land use concept for peatland that can combine the provision of essential mire ecosystem services with the production of useful biomass. Ideally even carbon sequestration can be achieved by the formation of new peat. In future paludiculture should be the normal case for land use on peat soils, drained peatland use should be the exception.
See also: Wichtmann, W., Schröder, C. & Joosten, H. (2016): Paludiculture – productive use of wet peatlands. Climate protection, biodiversity, regional economic benefits, Schweizerbart Science Publishers, 272 p.
Keywords: paludiculture, land-use concept, reed

Potential of paludiculture in selected peatland areas in Austria

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Austria has more than 1,550 mires and peatlands – with varying (protection) status. At least 63 % of the total peatland area (with a minimum peat depth of 30 cm) has been degraded due to intensive agricultural or forestry use for decades or even centuries.
In order to minimise that number and area of degraded peatlands, we want to establish wet land use options, and try to regain their original functions as much as possible. A wet peatland can store carbon and serve as an agricultural or forestry site at the same time – which is only little explored in Austria so far. Our project is the first one examining the potential of establishing paludiculture in Austria. We chose five regions, including two positive ideals: litter meadows in the eastern (Burgenland) and western part (Vorarlberg) of Austria that could act as role models. In Burgenland, 42 farmers implemented extensively cultivated meadows for oxen ("Moorochsen"). Vorarlberg is the only state of Austria that implemented a litter meadow regulation ("Streuwiesen-Verordnung") so far. Furthermore, we want to analyse three regions with partly severely drained peatlands. These areas are either intensively cultivated as grassland or forested, surrounded by drainage systems, or peat is still extracted, although in a small-area. Even conservation areas only partly profit from the protection status and are negatively affected by agricultural cultivation and drained soils.

The overall aim is to conduct an analysis of potential pilot areas, to work out site-specific paludiculture options with the affected stakeholders, and to recognise traditional land-use that qualifies as paludiculture.
http://geooekologie.univie.ac.at/en/projectsresearch/current-projects/
Keywords: rewetted peatland, ecological restoration, peat bog, fen

Better Wetter - Paludiculture for future-proof water management

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The Better Wetter program is a regional initiative, that searches for options to turn around the water management system in the North East of the Dutch province of Fryslan. The current water management system can be typified as 'land use determines water level'. We investigated how this can be changed to 'water level determines land use'. The current system leads to soil subsidence due to peat oxidation and compaction. Currently, the deepest polders have a surface elevation around 1,75 m below sea level. This leads to increased flood risks and risks of saline groundwater extrusion.
In 2016, we started our first pilot studies with paludiculture as component in a future-proof water management system. We focused mainly on growing *Typha latifolia*. Several student projects investigated the potential of *Typha* stands for aquatic macrofauna, potential yields and the most promising locations from a water management perspective. Market options for *Typha* products were investigated. After a pilot in 2016, the first *Typha* growing test fields will be planted in the spring of 2017. We will test different methods of planting: starting from seed, using root stalks, and several plant densities will be tested.
We present results from an ongoing project. Results include investigations into the contribution of *Typha* growing to aquatic macrofauna, potential yield projections, some marketable products, best growing conditions for *Typha*, and preliminary results of the field tests of best planting methods.
Keywords: case study, project setup, preliminary results

Estimate and utilisation potential of the reed biomass from the Ili Delta, Kazakhstan

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Central Asia is the region with the worldwide highest number of endorheic or closed river basins. Many of those river basins are transboundary ones. Within those river

basins, riparian ecosystems, wetlands, and riparian forests, the most productive ecosystems offer a huge potential for utilisation ranging from biomass harvest to tourism. Following the desiccation of the Aral Sea, Lake Balkhash has become the largest lake of Central Asia with an area of 17,000 km^2. The Ili Delta, in total 8,000 km^2, is the largest natural delta and wetland complex of Central Asia. 70% of the Ili River's runoff is generated in China, so, the Ili Delta is a show case for a wetland complex lying downstream in a transboundary river basin. The objective of this paper is to assess the area and distribution of the wetlands and *Phragmites australis* dominated reed vegetation as major natural ecosystems in the Ili Delta and their current and potential utilisation. An analysis of Rapid Eye satellite images revealed that there are wetlands and reed vegetation on a total area of 211,778 ha in the Ili Delta, 85,400 ha are submerged reed beds, with a total estimated biomass of 869,097 tons. *Phragmites australis* is used as fodder and raw material. Currently, there are about 100,000 livestock grazing in the delta. The submerged reed is used by a factory for chipboards that could substitute wooden chipboards. Reed biomass is investigated as feedstock for bio-polymers, e.g. Poly-Lactat. In 2014, almost 10,000 tourists visited the delta. Most of all tourists come from Almaty, followed by Russia, other regions of Kazakhstan, and Europe (outside Russia).

Keywords: *Phragmites australis*, ecosystem services, dryland region, endorheic river basin, raw material, construction material, polylactat

Trends of wetland tourism in Muthurajawela wetland sanctuary, Sri Lanka

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Tourism has experienced continued growth and deepening diversification to become one of the fastest growing economic sectors in the world. Wetland ecotourism is a key part of global tourism. Sri Lanka has unique kinds of inland and coastal wetland ecosystems which harbor a rich biological diversity that has high potential to develop ecotourism operations. Muthurajawela wetland sanctuary is such a kind of wetland, and the largest coastal peat bog of Sri Lanka. It is recognized as an ecologically significant wetland in the country. This study is based on foreign tourist visitations to the Muthurajawela Visitors' Center (MVC) during 2008 to 2015 and the main objective was to identify the trends of foreign tourist arrivals over the study period. July was the month with the highest average foreign tourist arrivals recorded to MVC. May was the month with the lowest foreign tourist arrivals recorded to the country and MVC. The number of foreign tourist arrivals to the country and MVC

over the past 8 years increased annually. However, the percentage of foreign tourist arrivals to MVC from total arrivals to the country is slightly decreasing. The Sri Lankan government should take steps to develop the wetland tourism sector in Sri Lanka as a major way of earning foreign exchange, but the usage of wetland tourism for developing tourism sector in Sri Lanka is questionable.
Keywords: Muthurajawela, Sri Lanka, tourism, trends, wetland

Experimental data on the cultivation of cane plants using the method of vegetative propagation, on an experimental plantation in the developed peat deposits in the Tver Region

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In 2014, the Tver State Technical University in Russia started within a German-Russian project to restore wetlands in order to prevent fires and mitigate climate change. In order to obtain biomass work was carried out on the artificial reproduction of an ordinary cane plants (*Phragmites australis*). The main method chosen was vegetative propagation of plants - sections of rhizomes with dormant buds. The scope of work on the primary development included the following process steps (including the sequence of their conduct): the mechanical removal of the aerial part and root system of weeds, removal of the bottom layer of peat, and the layout portions of the surface. Harvesting of planting material was carried out on the day of bookmarks plantations, except storage. The experiment used two schemes landing: 70h25 and 45h25 cm, ie, aisle in the first embodiment is 70 cm, the distance between the rhizomes portions are 25 cm in the row. Second embodiment - a thickened planting: aisle - 45 cm, the distance between portions of the rhizomes in 25 cm row. Survival, growth, development of plants, and the formation of the biomass in the first and subsequent years of life are to a large extent dependent on the conditions of temperature and moisture. Before leaving in the winter overall experimental plots were characterised, the average height above ground shoots ranged from 15 - 30cm. Generative shoots were absent. On average, only 20-25% of the rhizome sections were able, during the first year after planting, to form a small above-ground vegetative mass portion. The rhizomes grew from one to 3 advanced escape. During the growing season 20-25% of the planting material died off. Viable rhizome (70-75%) had a well-developed root system and buds. In the second year of life, plants maximum of wet and dry above-ground biomass with optimal hydration was 3.27 and 1.87 t / ha, respectively. The number of generative shoots was equal to 59.9 pcs. On an experimental plantation (in the growing season 2016) collection of wet and dry above-ground biomass is equal to: the width between the rows when planting 45 cm - 3.81 and 2.23 t / ha, with a width of 70 cm - 2, 54 and 1.49 t / ha, respectively.

Thus, the experience of the artificial cultivation of cane to produce biomass method of vegetative propagation in pilot sites in the Tver region has allowed to identify the main elements of the technology, which will be the basis for the creation of industrial plantations of the marsh plants.
Keywords: worked out peat deposits, biomass, planting and growing

The soil and the biodiversity of the paramo ecosystem, Ayabaca, Peru

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The grass ecosystem, with the local name paramo, is situated in the north of the Andes cordillera. These are characterized by high humidity, which supply water for the formation of the river. The high humidity is a consequence of the plant accumulation through low temperature, the glacial and volcanic soil. These characteristics permit the presence of the paramo ecosystem. This study was compiled in Frias, Ayabaca province, Peru between 3,089 and 3,363 m above sea level. Soil and plants were collected in 30 parcels. The results of the study discusses the influence of the soil and plants in the water retention of the soil under overgrazing condition.
Keywords: paramo ecosystem, water regulation, soil

A Colchis Lowlands master plan - Long-term development and conservation

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During the centuries on the lowland of Kolkheti, there was formed tradition of relation of human with nature that basically meant protection of the nature and usage of its resources economically. During times in Kolkheti, in the process of anthropological impact, in some cases forest experienced influence of peat, in other cases peat experienced influence of forest. Today, in spite of fact that Kolkheti National Park was found, situation about conservation of biodiversity is unenviable. One of the basic danger is reclamation works, which is intensively going on the South area of Kolkheti National Park, aim of which is drainage of area which is useful for subtropical agriculture. There are planned wider reclamation works on the nearby territory of National Park. The economic situation of the population is poor, most of them live in poverty and they have not right to use their natural resources. They don't have means for heating, as stock of timber is run off and there are separated unapproachable places for finding firewood. Accordingly, they canot find enough amount of firewood.
Thereby it is necessary that also the conservation needs with regard to the KNP surroundings are considered. As described above the conservation of the ecosystems

in the Kolkheti National Park do not only depend on management and conservation activities inside the protected areas, but also on activities adjacent to the Park. Thus a long-term strategy is essential that includes the future development of the adjacent rural areas and conservation needs of the Park's ecosystems.

A Colchis lowlands master plan is described in follow. The Colchis lowlands can be considered to consist of four zones: The sea, which allows and facilitates value creation (via fishery, transport, trade, tourism), The coastal zone, directly along the coast, where most value creation (economic activities) takes place and most habitation (permanent and temporal population) is situated, the green belt behind the coast with its important nature areas, which have important ecological values (provision of ecosystem services and biodiversity) and create economic value both directly within the zone (ecotourism) and indirectly for the coastal zone (ecotourism, life quality for people and companies living and working there), the hinterland, the remaining extensive lowlands, which are low productive and only sparsely populated. In former times, the hinterland largely consisted of wet forests on clayey soils. These forests have been cleared and drained to make place for agriculture. The clay soil and the high amounts of precipitation, however, prevent an adequate drainage for conventional, drainage-based agriculture and as a result the use of the hinterland is currently limited to low-intensity, low productive grazing.

The removal of the forest and the construction of extensive drainage infrastructure have strongly decreased water retention capacity in the area, with the result that surplus water from the area (and its upstream catchment) is rapidly removed downstream in the direction of the green belt and the coastal zone, where this water causes severe floods.

Thus, imaginary problems in the hinterland (i.e. the low value area) where water is rapidly removed without relevant local benefits, are "solved" by creating huge problems in the green belt and the coastal zone (i.e. the high value areas). Mitigating and solving the real (expensive) problems in the high value areas (floods, eutrophication) is possible by (cheap) measures in the low value areas. The solution is to change the drainage based low productive agriculture in the hinterland to wet agriculture and forestry (paludiculture, Wichtmann et al. 2016). The paludicultures will produce useful biomass (e.g. for energy, construction, and fodder) while offering simultaneously room for flood water retention. During floods, the high water will be stored longer in the hinterland and slowly released so that peak flow towards the green belt and coast do no longer occur.

We observed several changes in the boundaries of the KNP within the last years without adequate justifications like excluding the dunes of the coastal strip. To ensure a long-term conservation such changes has to be avoided, also with regard to changes in zonation in the Protected Areas and adjacent areas as it provides stakeholders long term planning security by showing that policies do not change ad hoc and really needs an adequate justification.

Keywords: Kolkheti, strategy, paludiculture

Sphagnum restoration on degraded blanket and raised bogs in the UK using micropropagated source material: a review of experimental trials

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There is an increasing demand for a supply of *Sphagnum* to facilitate the restoration of bogs in damaged landscapes and in the developing practice of Sphagnum farming. Usually, *Sphagnum* is translocated from donor to receptor sites and spread at a diluted rate to cover large areas of bare or degraded peatland. However, this practice is often constrained by a limited source of local, donor *Sphagnum* of the desired species and by a range of difficulties inherent in the transfer of the moss from one site to another. To overcome these problems, here we describe the propagation of *Sphagnum* from vegetative material in sterile tissue culture and the potentially unlimited production of juvenile plants in a variety of forms. Field trials on degraded upland blanket bog and on a lowland cut-over peatland in northern England over 10 years explored the planting methods and potential of this new approach for *Sphagnum* production. The challenges faced in establishing micropropagated *Sphagnum* plants on peatland surfaces in challenging environments appear comparable to the usual issues encountered in conventional *Sphagnum* restoration and cultivation. Our results show that micropropagated *Sphagnum* provides a productive and reliable form of propagule offering great potential in restoration and Sphagnum farming.

Keywords: peatland restoration, wetlands, *Sphagnum*, tissue culture

Comparative photosynthesis, respiration, and growth of micro-propagated *Sphagnum* species

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Intact peatlands have globally-recognised Ecosystem Service benefits, particularly in flood mitigation and carbon storage. Human actions, including widespread drainage and peat-harvesting, have all but eradicated these important functions and caused a decline in *Sphagnum*, the key feature of peatland habitats. MicroPropagation Services Ltd (MPS) use tissue culture techniques to produce rapidly-growing and disease-free source material in bulk for both conservation, restoration, and for Sphagnum farming, which could be an economic alternative to peat harvesting or drainage for conventional agricultural crops on peat. Other horticultural users of *Sphagnum* mosses could be supplied from micro-propagated products, reducing harvesting from 'wild' sources and habitat damage. One of these products, BeadaGelTM, is a mix of *Sphagnum* species in a hydrocolloidal gel, sprayed directly onto the peat surface.

Growth trials compared species productivity to identify the most beneficial species mix.

Eleven *Sphagnum* species, separately and mixed, in BeadaGelTM form, were grown on peat substrate in clear acrylic pots both indoors and outdoors, and harvested when the most vigorous plants reached the pot tops (eight months indoors and eighteen months outdoors). Samples of six species of *Sphagnum* were also harvested (at seven months) from ideal temperature- and humidity-controlled growth conditions in MPS greenhouses. Species were ranked in terms of height, volume, and dry weight density, providing evidence to determine the *Sphagnum* species of choice whether for conservation, farming, or other economic uses. Photosynthesis rates of 'wild' *Sphagnum* species were measured by leaf chamber analysis to aid the interpretation of growth results. Rank correlation between 'wild' species photosynthesis and BeadaGelTM species growth (by dry weight) was Spearman's rho = 0.8 and 0.73 for indoor and outdoor samples respectively, but -0.6 for greenhouse samples. Current research is exploring further the comparative CO_2 gas exchange and growth of micro-propagated *Sphagnum* species.

Keywords: *Sphagnum*, micro-propagation, growth, photosynthesis

Development of a tool for the decision making process in identifying peat substitutes for growing media

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Mining of peat as a raw material for the production of growing media and potting soil is associated with major ecological problems: greenhouse gas emissions, loss of biological diversity, and changes of the water supply on a landscape scale. Peat substitutes in growing media such as composted bark, wood, and coconut fibres are added only in small proportions so far, since they have different properties compared to peat, and therefore they can cause risks in crop production. Moreover, they are not available in sufficient amounts, and can also result in ecological problems (e.g. energy-consuming transportation of coconut fibre).

Therefore, the main objective of this project is the development of a tool for the decision making process by which new raw materials as peat substitutes in growing media and their potential risks in crop production can be identified as well as provisions for a safe cultivation can be suggested. On the basis of the decision tree different parameters are analyzed systematically. Already, in an early stage it can be indicated if a raw material is suitable as a growing media component or if it has to be discarded.

For this, analytical methods for the characterization of the chemical, physical, and microbiological properties of raw materials and potential new growing media components (VDLUFA, DIN EN) are developed. Also methods established in soil science are further enhanced developed in cooperation with the processing industry (processing of raw materials / composting, production of growing media).

In the context of this study, several potential growing media components (alder, reed, cattail, heath) were tested by these methods. These are renewable raw materials, which could partly be grown as paludiculture. First results of laboratory and greenhouse experiments on these potential growing media components are presented.

Keywords: peat substitute, growing media, renewable raw material, paludiculture, horticulture

Experiments on restoration of raised bog vegetation cover in abandoned part of cut-away peatland

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The first small-scale experiments on spreading of *Sphagnum* mosses in cut-away peatland were implemented in Aukštumala peatland (Western Lithuania) in 2011–2012. A total of 130 patches (0.4×0.4 m in size and 5–7 cm thick) of typical raised bog vegetation were planted on the bare peat substrate in the specially prepared part (0.12 ha) of cut-away peatland. More resistant to changes in soil moisture the species of *Sphagnum fuscum, S. magelanicum*, and *S. capillifolium* dominated in the planted patches. Due to the fact that the peatland is still used for peat cutting, it was difficult to maintain ground water level depth adequate for the development of raised bog vegetation. The results of the experiment showed that in the next year after the planting, 93% of the planted fragments established successfully. Twenty-two plant species from 12 families were recorded at the experimental site. About 68% of the recorded species (*Agrostis capilaris, Bidens tripartita, Frangula alnus, Gnaphalium sylvaticum, Lycopus europaeus, Lysimachia vulgaris, Molinia cearulea, Salix aurita, S. cinerea, Taraxacum officinale*, etc.) were atypical to ombrotrophic bogs. The most significant changes in the vegetation coverage were ascertained for *Vaccinium oxycoccus* (the coverage increased from 5 to 18%), whereas the mean cover of *Sphagnum* spp. increased only by 4% during the first two years of the experiment. Due to unfavourable hydrological conditions at the experimental site (ground water level depth during the vegetation period varied from -45 to -82 cm) and dry growing seasons in the last three years, a total vegetation coverage of typical ombrotrophic plant species decreased from 58% (in 2012) to 14% (in 2016). Maintenance of optimal water level is one of the most important ecological factors for successful establishment of raised bog plants at restoration sites. Therefore, currently, the elaboration of water level regulation and maintenance system in Aukštumala peatbog is being carried out. All restoration activities will be implemented by the support of LIFE+ programme project LIFE Peat Restore LIFE15 CCM/DE/000138.

Keywords: *Sphagnum*, restoration, cut-away peatland, raised bog vegetation

Harvesting, characterization and potential use of *Sphagnum* for the horticultural industry

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Although *Sphagnum* is well known for its ecological role in peatlands, much remains to be studied concerning the possible use of its fiber in horticulture. The peat industry is increasingly interested in *Sphagnum* moss, because of its high porosity and high capacity in water retention. Because of its properties, *Sphagnum* can replace perlite and vermiculite, non-renewable raw materials, imported by Canada. When grown, *Sphagnum* moss is renewable and can be produced in peatlands at the end of exploitation. This makes it possible to restore these disturbed wetlands, give them a second economic life, and create employment in the regions concerned.

In Canada, the craze for *Sphagnum* cultivation begin to gain hold in several industries. In summer 2014, an experimental *Sphagnum* moss site was established in Shippagan, New-Brunswick (Canada) (NB), to develop techniques for growing *Sphagnum*. The Coastal Zone Research Institute (CZRI) focuses its work on two main topics: (1) the development of *Sphagnum* harvesting techniques, and (2) the characterization of *Sphagnum* moss for horticultural purposes. Water properties as well as microbiological, chemical, and physical properties were measured on several *Sphagnum* species harvested at different seasons and dried various ways. Growth trials were also done considering diverse volumetric proportions. The results showed a great potential for *Sphagnum* moss in growing substrates for flowering plants and vegetables. | http://www.irzc.umcs.ca/flash_content/anglais/tt_apercu.html

Keywords: Sphagnum farming, horticulture, *Sphagnum* harvesting techniques

Sustainable BeadaMoss® micropropagated (clean) *Sphagnum* for Sphagnum farming & restoration - providing a pure *Sphagnum* crop

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17 species have now been micropropagated, enabling pure species to be grown in very large quantities and ensuring clean, pest, disease, and weed free *Sphagnum.*

Micropropagated *Sphagnum* (BeadaMoss®) of a wide range of species has been shown to establish and grow profusely on both Upland and Lowland restoration sites, when applied as the BeadaMoss® range of products.

Analysis shows that one litre of BeadaGelTM contains/produces ~33,000 strands/ plants and is ideal not only for restoration, but also has huge potential for establishing pure species, weed free for Sphagnum farming.

Growth rates, biomass, and volume of *Sphagnum* are being studied, along with the optimum conditions required for maximum growth. Comparison of the current 17 species is being made to select the best performing for Sphagnum farming. Genetic variation within species is also being studied as production of clonal stock allows easy comparison and selection.
The growing of uncontaminated pure single species is one of the major advantages of BeadaMoss® micropropagated *Sphagnum*, and the assessment and selection of species most suitable for use in growing medium are underway. Physical, chemical and biological characteristics of a range of species and clones are being assessed.
Local origin *Sphagnum* can be produced for restoration and only requires a few strands as starting material. Such material has been applied to over 1,500 hectares of peatland. BeadaMoss® removes the need to take *Sphagnum* from the wild.
GHG analysis and the benefits of restoration with BeadaMoss® are being studied in the field and under controlled conditions, early results will be discussed.
The economics of using BeadaMoss® products for Sphagnum farming are about to change, with the development of an improved product and production process, which when it is large scale will potentially reduce costs to approx. 1/10 of current prices i.e. to ~€6,000/ha, producing a crop worth many times that.
www.BeadaMoss.co.uk
Keywords: sustainable *Sphagnum*, BeadaMoss, Sphagnum farming, restoration

Peatlands and floodplain meadows support sustainable and resilient future

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Restoration and conservation of different types of wetlands is obligatory to provide several ecosystem services for a sustainable and resilient future. Getting started with restoration projects for wetland habitats, it is appropriate to find the most environmentally-friendly socio-economical function for the selected site. One option is to support local bioeconomy via bioenergy production from substrates of monocultivated extracted peatlands or semi-natural communities. Therefore, information about biomass yield and crucial characteristics for bioenergy production is required in order to analyse its feasibility and sustainability. In our analysis we compared the production and chemical characteristics of biomass from two different types of wetland: floodplain meadows and extracted peatland cultivated with reed canary grass. In Estonian mid-summer conditions we obtained about 30% more biomass from floodplain meadows compared with a fertilized monoculture in extracted peatlands. Even with late harvest in floodplain meadows in August, the biomass yield was about 10% higher than that in cultivated and fertilized extracted peatlands two months later.

It has been demonstrated that biomass chemical characteristics varied by origin and by time. Autumn harvesting is suggested for reed canary grass in terms of briquetting and heating. For biogas production, havesting in July would be more reasonable. Similar options can be exploited for biomass from floodplain meadows. Due to more diverse vegetation in floodplain meadows and thus more heterogeneous biomass, these may offer a wider range of potential applications as different biobased products.
Keywords: biomass, bioenergy, natural vegetation, reed canary grass, restoration, sustainable management, wetland

The energy potential of soft rush (*Juncus effusus* L.) for different utilisation pathways

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Rushes are prominent wetland plants of the genus *Juncus*, occurring world-wide in a broad range of species. They are well adapted to conditions of waterlogging, and often provide crucial ecosystem services in natural peat- and wetlands. Tall rushes like *Juncus effusus* offer a great biomass potential as they tend to dominate the vegetation, especially under periodically wet conditions. Moreover, using rushes as retention plants to clean waste water can also lead to high yielding stands. Removing rush biomass is often necessary to enhance the ecosystem services for a variety of reasons (removal of nutrients, encourage regrowth, reduction of competition, and providing habitats for birds). There is almost no value of rush for livestock feeding, and if rush stands need to be harvested, it makes sense to utilise them in different ways: the use for energy purposes seems to be the most promising one.

We investigated three alternative energy utilisation pathways for rush biomass, and evaluated their energetic conversation efficiencies: biomethanisation via wet fermentation technique (a), biomethanisation via dry fermentation technique (b), and combustion (c). Batch experiments (a), experimental fermenters (b), and thermocalorimetric equipment (c) were used to measure energy output per unit rush biomass input. We assessed the conversation pathways economically on the basis of average costs for provision and delivery of biomass and assumed average conversation costs derived from surveys and up-to-date reference tables.

The wet fermentation technique had significantly higher biogas yields than dry fermentation (399 l $N \cdot kg^{-1}$ DM compared to 258 l $N \cdot kg^{-1}$ DM). These yields constitute 59 % and 43%, respectively, of the superior biogas potential of maize silage as a reference. Nevertheless, low costs for substrate production make energetic utilisation of *Juncus effusus* an interesting alternative, provided that short distances between fields and biomass conversion plant can be realised.

Keywords: rushes, biogas, energy

Combustion quality of paludi-pellets from rewetted fens in Northeastern Germany

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Paludiculture („palus“ lat. swamp) is an agricultural use of wet peatlands which maintains the peatbody for carbon storage. The aboveground biomass can be used as renewable energy.
In this study, biomass from paludiculture was pelletised at lab and industrial scale. Process parameters as well as characteristics of the pellets were analysed with regards to the normative standards of DIN EN ISO 17225-6. Besides the production of the pellets, the focus of this study was to classify the pellets for energetic use. Additionally, the paludi-biomasses were mixed with pine wood (portion of 50 % and 80 %) to assess the influence of different mixtures to the combustion characteristics.
On lab scale summer harvested sedges (*Carex acuta*), winter harvested Common Reed (*Phragmites australis*), and Reed Canary Grass (*Phalaris arundinacea*), as well as mixtures with pine chips were pelletized. For industrial scale (mobile pellet machine) thatch waste material (*Phragmites australis*) from winter, as well as summer harvested sedges (*Carex acuta*) and Reed Canary Grass (*Phalaris arundinacea*) from mixed stands were used.
The produced Reed and Reed Canary Grass pellets from winter harvest could meet all the normative standards of DIN EN ISO 17225-6, except the abrasion resistance. Relating to the unfavourable chemical elements nitrogen, chlorine and sulphur sedge and Reed Canary Grass pellets show increased chlorine concentrations because the biomass was harvested in summer. Mixed pellets with pine chips of these grasses could also meet the required standards.
Keywords: pellets for energy, biomass quality, DIN ISO 17225-6, biomass from paludiculture

Developing a climate-smart local energy supply with paludiculture

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To avoid high GHG emissions from peatlands which are drained for agricultural land, land use change is needed. To substantially reduce GHG emissions as well as subsidence, water tables need to be raised to (near) surface level. After raising water tables, vegetation composition will gradually change to species adapted to wet conditions. By using site adapted machinery the biomass can be harvested, but still the question arises what to do with that biomass which is not suitable as fodder. The most promising option is to use this biomass for local district heating. Since 2014 the Agrotherm GmbH has operated a local heating plant in the town of Malchin and has demonstrated that this way of using biomass is possible.

To transfer the new utilisation option to other sites land users, which can produce the biomass, need to be linked to sites and companies which have a need for heat. To support the establishment of further district heating plants fed by biomass from wet peatlands, we carried out a survey for: a) existing peatland site planned for rewetting or already rewetted where the biomass could be provided, and b) suitable location for new heating plants or site where fossil fuels could be substituted.
To identify suitable production sites for the biomass as well as sites with heat demand we set out a list of criteria, which can help to realise new projects. In the district of Vorpommern-Rügen these criteria were exemplary applied. About 14 % (44,343 ha) of the rural district is covered with peatland, of which about 23.800 ha are in (drainage based) agricultural use. It was assumed that about 1,890 ha of the used peatland is already suitable (more or less wet, less or reduced GHG emissions from the production site) to provide biomass for eight local heating plants (each with a performance of 1,000 KW). For ten sites we worked out and checked the basic parameters for the installation of a heating plant. At six sites an installation of a heating plant is promising. At these sites further support is needed to link land user, local authorities and heat providers.
Keywords: biomass utilisation, community heating

Wetland Energy – renewable energy production on former excavated peatlands in Belarus

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"Wetland Energy", a Europe Aid funded project was implemented in Belarus by the Michael Succow Foundation for the Protection of Nature (MSF) in a partner consortium with several in country partners. These partners are the International Sacharov Environmental Institute (ISEI), the Institute for Nature Management (IfNM) of the National Academy of Sciences, and Ltd. Peat briquetting factory "Lidsky" (LPF). In close cooperation a successful pilot for sustainable energy biomass production in degraded peatlands after rewetting (Paludiculture) was developed, analysed, and implemented.
Field investigations were carried out on pilot sites on partly excavated fen peatland at LPF, in the Grodno region and in near nature fens in Yaselda river valley at Sporovsky Zakaznik (Brest region).

From 2012 to 2015 vegetation-ecological and hydrological monitoring, GHG emission measurements, and economical assessments were executed. The results led to the establishment of an adapted production line for reed biomass based pellet and briquettes at LPF. The facilities are ready for production and further optimisation of the weaknesses and bottle necks that have been identified by the project. If the obstacles during this pioneer phase can be overcome an upscaling to national level in Belarus seems to be possible. In Belarus, potentially ~400,000 ha of drained and degraded peatland are available and could benefit from Paludiculture. To substitute the energy equivalent of ~800 mio m^3 gas that is provided by the Belarusian peat industry for the energy sector annually only ~220,000 ha of paludiculture area for energy biomass production would be needed. This approach could substitute the fossil energy resource peat on a large-scale and therefore contribute to peatland restoration and the mitigation of environmental problems related to drainage based peatland utilisation and energy peat-mining in Belarus. http://www.succow-stiftung.de/wetland-energy-sustainable-use-of-wet-peatlands-in-belarus.html

Keywords: reed biomass pellets and briquettes, energy peat substitution, peatland rewetting

Germination and early growth patterns of two *Typha* species – the first year of establishment

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The presented poster combines the results of two closely related experiments with the two plants *Typha latifolia* and *Typha angustifolia*. At the moment, the two species are in the focus of economists, farmers and environmentalists because of its quite unique tissue features and its ability to retain nutrients from soil and water. The *Typha* plant is not yet recognized as a crop, so we still lack information about how to optimally cultivate it. The first experiment shows growth patterns of early plant stages depending on different availabilities of the macronutrients nitrogen, phosphorus and potassium. A nitrogen gradient and different N:P ratios were conducted under laboratory conditions on peat. Because of so far unsolved problems, the plants did not show a normal growth, but a tendency for better development with higher nutrient concentration became visible. The second experiment was conducted as a field study within an active grassland. The two *Typha* species were cultivated in four lowered, water filled basins to simulate the rewetting of the site. A water level gradient (0 to 70 cm above ground) was installed to collect data on the growth patterns of the plants depending on the water level. The results show a clear optimum of water level for the two species.

They showed the best increase in biomass per square meter and total number of new shoots at a depth of around 30 to 40 cm above ground.

Keywords: *Typha*, seeding, population ecology, paludiculture

Sphagnum cultivation in the Peat Meadow Landscape: bottlenecks and opportunities for restoring ecosystem services

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Globally, many wetlands including peatlands have extensively been drained for agricultural use, resulting in severe land subsidence and loss of important ecosystem services such as carbon (C) sequestration, flood protection, and water purification. To halt land subsidence, these peatlands are rewetted by increased rainwater storage or sub-optimal surface water supply. Previous reports show that increasing water storage already transforms drained peatlands into considerable sources of methane (CH_4). Furthermore, rewetting of former agricultural peatlands is expected to cause eutrophication due to the high nutrient availability in the soil, which may compromise the restoration of C sequestration by negatively influencing the regrowth of peat forming vegetation such as *Sphagnum* spp.

We compared C fluxes of a rewetted former agricultural drained peatland in the Netherlands with its control situation, and additionally used a controlled laboratory approach to study potential side effects of rewetting with P and HCO_3- rich surface water compared to rainwater. Besides, we tested measures that may reduce negative side effects, including topsoil removal and the application of *Sphagnum* spp. We conclude that rewetting of drained peatlands, and applying *Sphagnum* greatly reduces CO_2 emissions without increasing CH_4 fluxes. Topsoil removal will, at least in initial stages, strongly reduce the emission of nutrients and greenhouse gases. The storage of rainwater rather than surface water is preferred to reduce mineralisation rates and enable *Sphagnum* growth. In order to optimize the total C balance, the removed topsoil should be re-used in subsiding agricultural peatland areas.

Keywords: peatlands, *Sphagnum*, rewetting, restoration, nutrients, carbon, methane, emissions

The effect of Sphagnum farming on the greenhouse gas balance of donor and propagation areas, irrigation polders and commercial cultivation sites

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The rewetting of drained peatlands, in order to restore their natural function as a sink of atmospheric carbon, is an important measure for climate protection but hinders conventional economic use.

One possible way to combine ecological and economic goals is Sphagnum farming, i.e. the cultivation of *Sphagnum* mosses as high-quality substrates for horticulture. The presented work evaluates the attempt of commercial Sphagnum farming on former peat extraction sites in north-western Germany with respect to the exchange of greenhouse gases.

The exchange of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) of the whole peatland-based production chain comprising a donor mire, a propagation area, an irrigation polder, and a commercial cultivation site will be determined in a high temporal resolution for two years using manual chambers. This will allow evaluating the greenhouse gas balance of Sphagnum farming sites in comparison to near-natural sites and the potential of Sphagnum farming for restoring drained peatlands to sinks of atmospheric carbon. A variety of biotic and abiotic factors will be evaluated, such as different *Sphagnum* species (*Sphagnum palustre* L., *Sphagnum papillosum* Lindb. and a mixture) and the effect of different irrigation techniques. Additionally, selected plots are equipped with open top chambers in order to examine the greenhouse gas exchange under potential future climate change conditions. First results will be presented.

https://www.thuenen.de/en/ak/projects/sphagnum-farming-effects-on-biodiversity-and-climate-protection/

Keywords: Sphagnum farming, greenhouse gas balance

Summer CO_2 and CH_4 fluxes from emerging *Sphagnum* lawns in a rewetted extracted peatland in Sweden

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16 years (2015) after rewetting a nutrient-poor extracted peatland, a functioning wetland ecosystem with stable hydrology and characteristic peatland vegetation has been established. *Sphagnum* spp. appeared 7 years after rewetting, covered 12 % and 22 % of the investigated areas after 13 and 14 years, respectively, and was the most abundant species together with *Eriophorum* spp. Some parts of the restored wetland are covered by almost 100 % *Sphagnum* and terrestrialisation by *Sphagnum* of the newly established shallow lakes is proceeding rapidly.

Thus, due to the *Sphagnum*'s high growing potential, restored wetlands could act as prime *Sphagnum* harvesting sites. To monitor the *Sphagnum*'s climate impact and to compare newly established *Sphagnum* with *Sphagnum* from pristine bogs, sites with dense *Sphagnum* lawns were investigated for greenhouse gas fluxes in summer 2015. Transparent automated chambers connected to an infrared laser absorption gas analyser provided continuous measurements of methane (CH_4) and carbon dioxide (CO_2) fluxes.

In June, July, and August 2015 the *Sphagnum* sites were clear CO_2 sinks (-15, -28 and -15 g CO_2-C equivalents m^{-2}) but also CH_4 sources (28, 22, 55 g CO_2-C equivalents m^{-2}).

Adding for both gases, the sites were sinks in July (-6 g CO_2-C equivalents m^{-2}) and sources in June and August (13 and 40 g CO_2-C equivalents m^{-2}). The *Sphagnum* sites contained some young single *Eriophorum vaginatum* plants, and they may also be influenced by *Eriophorum vaginatum* roots. This may explain the higher CH_4 emissions compared with CH_4 emissions from pure *Sphagnum* sites in other studies where plant-mediated CH_4 transport was minimised due to the absence of vascular plants.
The first *Sphagnum* harvesting studies will be undertaken in 2017 with continuous GHG flux measurements before and after harvest.
Keywords: high temporal resolution flux measurements, nutrient-poor peatland, restoration

Greenhouse gas balance of an establishing *Sphagnum* culture on a former bog grassland in Germany

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The cultivation of *Sphagnum* mosses on re-wetted peat bogs for use in horticulture is a new land-use strategy. For this reason, data on the greenhouse gas exchange of such systems is still scarce.
We provide the first greenhouse gas balances of a field-scale experiment on Sphagnum farming on former bog grassland in its establishment phase. Over two years we used closed chambers for measurements of greenhouse gas exchange on production strips of *Sphagnum palustre* L. and *Sphagnum papillosum* Lindb., as well as on irrigation ditches of the experimental field, in north-western Germany.
Methane fluxes of both *Sphagnum* species showed a significant decrease over the study period. This trend was stronger for *S. papillosum*. In contrast, the estimated carbon dioxide fluxes did not show a significant temporal trend over the study period. The production strips of both *Sphagnum* species were net greenhouse gas sinks of 5–9 t ha^{-1} a^{-1} (in carbon dioxide equivalents) during the establishment phase of the moss carpets. In comparison, the ditches were a carbon dioxide source and emitted larger amounts of methane, resulting in net greenhouse gas release of ~11 t ha^{-1} a^{-1} carbon dioxide equivalents. The origin of these emissions is not clear, since the water used for irrigation comes from the drainage of the surrounding peatlands. Nonetheless, we conclude that the area covered by irrigation ditches should be minimized during the design of Sphagnum farming fields. Overall, Sphagnum farming on bogs has lower on-field GHG emissions than low-intensity agriculture.
Keywords: Sphagnum farming, paludiculture, methane, carbon dioxide, ditches

MOORuse paludiculture on fen peatlands in Bavaria - Establishment, climatic impact & environmental effects, utilisation options and economic viability

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Over the past decades, draining and intensive agricultural use of organic soils have transformed peatlands from vital ecosystem service providers, to GHG emission hot spots. Agricultural use of peatlands currently contributes 4.9 % to the total national GHG emissions in Germany. Various studies show that raising the water level in combination with extensification of land use can lead to a reduction in GHG emissions from organic soil. As this often entails reduced agricultural activities or even abandonment, landowners are often hesitant to engage in restoration activities. The Bavarian project MOORuse is designed to test peat-restoring land use alternatives (paludiculture) in combination with partial or complete rewetting. The integration of conservation and utilisation facilitates the recovery of peatland ecosystem functions, prevents further mineralisation. It also allows for tests of a spectrum of biomass utilisation options, developing economically viable solutions, and further assessing their integration with regional value chains.

We will give a conceptual insight into the project and its components, and present first results for the establishment of six paludiculture plants (*Typha latifolia* and *T. angustifolia, Phragmites australis, Carex acutiformis* and *C. acuta, Phalaris arundinacea*) their GHG exchange response to different water levels as well as results on plant biomass utilisation options.

Through the comprehensive project approach we seek to develop new sustainable fen peatland management practices, specifically for the environmental conditions of southern German peatland ecosystems, which take into consideration biodiversity and ecological functions as well as economic viability and regional value chains.

https://www.hswt.de/forschung/forschungsprojekte/vegetationsoekologie/mooruse.html

Keywords: paludiculture, GHG emissions, organic soils, land use change

Greenhouse gas emissions from soils fertilized with anaerobically digested biomass from wetlands

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Riverine wetlands are one of the most important ecosystems. They provide many services and for local communities and on a global scale such as climate regulation, biodiversity maintenance, flood attenuation, and water purification. Biomass removed from wetlands is mainly used as bedding for cattle or as a raw material for the production of pellets. It may also be a substrate for the production of biogas,

while the post-fermentation material can be used as an organic fertilizer. Biogas residues applied to the arable land can reduce loss of organic matter in soils and provide nutrients necessary for development of crops, decreasing demand for synthetic fertilizers at the same time. When planning the use of digestate as fertilizer it should be noted that it may still be a source of greenhouse gases (GHG). The aim of the study was to determine the intensity of GHG emissions from the soils enriched with anaerobically digested biomass of plants removed from wetlands of the Narew River Valley, as a part of protective activities. In studies, chamber method was used and fluxes of the investigated gases were determined by GC method with universal BID (Shimadzu, Japan) detector. Studies have shown that the anaerobically digested biomass from wetlands can be a valuable organic fertilizer. On the other hand, it is a source of easily biodegradable organic compounds and its intensive mineralization in the soil causes the release of greenhouse gases into the atmosphere. Tested gases showed varying rate of release from soils fertilized with digestate. The emissions of CO_2 and CH_4 were short-lived, while N_2O emissions were maintained at elevated levels 2 weeks after fertilization. In spite of this, much higher losses, which amounted to several dozen percent of the amount supplied with digestate, in the case of carbon were observed.
Keywords: digestate, greenhouse gases emissions, wetland biomass

A black alder plantation improves the greenhouse gas balance of a degraded moist peat grassland

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Drained peatlands are strong sources of the greenhouse gases (GHG) CO_2 and N_2O. Peatland rewetting, often combined with the implementation of peat forming vegetation, aims to restore the GHG sink function that is characteristic for pristine peatlands. Black alder (*Alnus glutinosa*) naturally occurs in temperate minerotrophic peatlands (fens), and is also suitable for the cultivation of biomass on rewetted peatlands. However, only some information exists on if a black alder plantation can reduce the climate impact of restored peatlands.

We investigated the effect of a newly established black alder plantation on the net GHG balance of a degraded fen in north-eastern Germany during a two-year study (August 2010 – August 2012). We compared the alder plantation (Awet) with an extensively used meadow (Mwet) both characterised by very moist soil conditions and a drier reference meadow (Mdry) characterized by moderately moist soil conditions. CO_2, CH_4 and N_2O fluxes were measured monthly to bi-monthly with the manual closed-chamber method. Fluxes were calculated using a modular R script and gap-filled to obtain continuous daily fluxes.

Awet was a GHG sink of (-4.8 t CO_2-eq ha^{-1} yr^{-1}), Mwet was climate neutral (-0.03 t CO_2-eq ha^{-1} yr^{-1}), and Mdry was a GHG source of (15.7 t CO_2-eq ha^{-1} yr^{-1}). This was mainly caused by CO_2 uptake at the two very moist sites and a high CO_2 release at the drier reference site. In addition, Awet was a larger CO_2 sink than Mwet, likely caused by an additional CO_2 uptake of the alders. All sites were significant CH_4 sources, but N_2O emissions were negligible. Due to inundation following heavy precipitation in summer 2011 remarkable CH_4 emission peaks were found, which accounted for up to 70 % of the cumulated two-year CH_4 emissions. However, Awet emitted significantly lesser CH_4 than Mwet and Mdry. We assume that the alders decreased the CH_4 emissions due to their effective O_2 transport.

Our results indicate that rewetting and planting alders significantly improves the GHG balances of formerly drained fens within the first two years. Furthermore, only one wet summer significantly increased the CH_4 emissions of our study site, despite two-year average groundwater levels of -0.2 to -0.35 m. This highlights the importance of acknowledging extreme precipitation events and groundwater fluctuations for the derivation of reliable GHG emission factors.
Keywords: paludiculture, carbon dioxide, methane, minerotrophic fen, peatland restoration, mire conservation, peatland use

Options for the utilisation of peatlands depending on their location - support of the decision by DSS-TORBOS

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Conventional agricultural use of wetlands requires increasing drainage intensity. Until now, the way of utilisation and application of technical equipment as well as the knowledge how to use the land is based on drained areas. On the other hand, drainage, cultivation and fertilization cause degradation of the organic soils and the loss of biodiversity. Furthermore, a reduction of agricultural usability and yield capacity can be observed.

To advise and help farmers finding the best way to break this cycle, we have developed a digital tool. The Decision Support System (DSS) TORBOS provides management strategies for conventional agriculture used peatlands regarding a sustainable use. Based on the individual information provided by the user, the system suggests location specific options for future usage. These options are issued for different water levels and show the possibilities of value-added chains.

There are 10 different options for usage that are included in the process. For each of them, profiles were created that contain information about location suitability, vegetation management, harvest, infrastructure and logistics. Furthermore, recommendations are given regarding processing, marketing, funding and the impact on the peat soil. The profiles are also available separately in a brochure.

The DSS is based on a modular concept. Dichotomous decision trees are used as main model elements. Numerous aids are given to lead the user through the system. The DSS is available in the internet for free usage in Germany under www.dss-torbos.de.

Keywords: decision support system, land use options

Utilisation of biomass from wet fen meadows in a local heating plant

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With 17,810 ha ha of peatlands, the Peene valley is one of largest fen areas in Germany. The fens had been drained for agriculture but were rewetted during the 90s. The meadows at the west site of the lake Kummerow are affected by the rewetting of the adjacent area. The farmer Hans Voigt had to find new ways to use the changing vegetation since using it as fodder for his cattle was no longer feasible. During an R & D project together with the University of Greifswald, using the biomass

as solid fuel was tested and identified as a promising solution. In the following years, the farmer brought together different stakeholders in the nearby city of Malchin to realise the integration of an adapted biomass boiler in the existing heating grid. There the biomass is used to replace a natural gas fired boiler. The farmer is now mowing 300 ha of wet fen meadows dominated by sedges and reed canarygrass for landscape protection with adapted grassland machinery during periods with a low water table in summer. Approximately 6,500 hay bales are used per year to provide 4,000 MWh heat for 540 appartments, a kindergarten, two schools and serveral office buildings. The utilisation combines bioenergy with climate, landscape and water protection and results in benefits for biodiversity and tourism. After three years of operation and successful overcoming of the initial challenges the company is looking for further ways to use the biomass as raw material and for new solutions for the biomass harvest.

Keywords: heating plant, district heating, biomass harvest

Economic and ecological assessment of solid fuels from rewetted peatlands

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The use of biomass from rewetted peatlands can combine the reduction of environmental impacts from peatland drainage with the benefits of the substitution of non-renewable fossil resources by renewable raw material and fuel. The purpose of this contribution is to evaluate costs and ecological impact of the utilisation of this biomass as solid fuels. The scenarios considered in the assessment includes three harvest schemes, summer harvest of hay round bales with adapted grassland machinery, winter harvest of chaff with specialised tracked vehicles and winter harvest of reed for thatching. It covers the use of the biomass as chaff, bales or processed in a mobile pelleting plant. The fuel is combusted in a small 100 kW boiler, an 800 kW boiler within a local heating grid and a hard coal power plant. The assessment is based on direct cost calculation and greenhouse gas and energy balance largely following the guidelines of the ISO standards 14040 and 14044 for life cycle assessments. Primary data was collected on biomass productivity, harvesting, mobile pelleting, fuel properties and small and middle scale combustion. Further data was taken from literature and databases. The results show harvesting costs between 11 and 32 €/MWh, high processing costs for mobile pelleting (139 €/t) and heat generation costs starting from 50 €/MWh mainly influenced by usage rate and fuel costs. The results of the greenhouse gas and energy balance show net savings of around 60 to 85 % compared to the fossil equivalents. The assessment presents direct cost calculations and greenhouse gas and energy balances from harvest to utilisation highlighting benefits as far as greenhouse gas and energy balances are concerned while revealing that heat generation costs are hardly competitive compared to fossil equivalents, mainly because of high investment costs for machinery and boilers.

Keywords: pelleting, heat generation, GHG balance, energy balance

The results of the introduction of lowbush blueberry (*Vaccinium angustifolium* Ait.) on the developed riding peat bogs in the Belarusian Lakeland

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At least 50,000 ha of cut-away peatland fields of high-moor bog type from 300,000 ha of the broken marsh lands in the Republic of Belarus are suitable for development of secondary forest exploitation by creation of plantations of a new North American berry species – lowbush blueberry (*Vaccinium angustifolium* Ait.).

Work on an introduction of a lowbush blueberry in the conditions of Belarusian Lakeland (the north of the country) began in 2009. Observations of blueberry development suggests that biological rhythms of the species is in character of the climatic conditions of the region. A further success of its cultivation and a harvest in a number of years seems realistic. The resistance of shrub to impact of negative abiotic and biotic factors is its positive quality that has been shown in lack of damage signs by frosts during the winter period, and also in rather high resistance to complexes of the pathogens and insects provided by respectively 9 types of mushrooms and 24 types of insects. The capability of lowbush blueberry to formation of a continuous cover due to creation of new bushes from rhizomes determines not only it high competitive ability with weeds. Also it allows to provide important ecological function on protection of a peat substrate against the fires, a water, and wind erosion.

From the economic point of view an important advantage of lowbush blueberry is the early introduction in a fructification stage – in the third year after planting, of two year old rooted cuttings, the berry productivity reached in 2015 the maximum of 1,292.6 g from a bush or 8,660 kg from a hectare.

The conducted research developed recommendations about production of landing material of a generative and vegetative origin, terms and methods of creation of plantations, use of mineral fertilizers and rejuvenescence of bushes cover. The three first domestic grades – «Motego», «Janka», «Polovchanka» – are created.

Considering this fact and in view of results of our research we to conclude that in the country there are prerequisites for *V. angustifolium* cultural development.

Keywords: Lowbush bluberry, berry productivity, ecological function, Belarusian Lakeland

Community based assessment on biodiversity conservation and ecosystem services in Shkodra Lake watershed

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This assessment was addressed to the lakeside community whose activity impacts the natural resources. The study analyzed the relationship between ecosystem with human well-being, on the drivers of ecosystem degradation, power of action of state and community to protect wetlands can give more information to develop the approach of maintaining these services through management ecosystem for sustainability. This was exploratory research based on quantitative method and comparative analysis data. A questionnaire was disseminated as an instrument to collect data and measure attitudes. Questionaires provide numerous, reliable, and organised data, while maintaining anonymity to encourage response to sensitive issues. A research software tool „Qualtrics" was used as a fast and easy method to deliver the questionnaire, to collect on-line data, to keep anonymity, to encourage response to sensitive issues, and to process the data collected. In terms of involvement in the survey by gender, female respondents dominate with 60% in the total respondents participating. The main age group in the total respondents participating was 21-30 years old, representing 55% of the respondents. While age groups of the 41-50 years old and 31-40 years old respectively accounted for 24% and 15% of respondents.
Respondent's perceptions on freshwater ecosystems services in the Shkodra Lake basin accepted that community benefits are increased while ecosystem services are reduced, thus we are facing habitats degradation and biodiversity lost in the region (the average value of all means of ecosystem services' items = 3.49-S). Regarding their attitude towards four categories of ecosystem services, on the one hand the respondents showed sureness for the possibility of the ecosystem in Shkodra Lake to provide the cultural services and supporting services (respective means 3.92-S and 3.86-S), on other hand, they showed a conservative approach towards provisioning services and regulating services (respective means 3.32 and 3.37) of this ecosystem. Wetlands provide high-value ecosystem services that make 'major contributions' to human welfare. The awareness of local community for ecosystem services, the benefits of conserving and restoring of ecosystem's functions in wetlands, should act as a potent incentive for the protection of biodiversity and its integration into development plans and decision-making across all levels of civil society to government levels. The low participation of local community (59%) in this survey on the ecosystem services of Shkodra Lake basin shows their insufficient awareness for the benefits that nature provides them and their low feeling of responsibility to protect the nature of Shkodra Lake basin. The study provides graphics responding the level of knowledge on biodiversity

conservation and ecosystem services from the authorities responsible to services and their level respond. | http://shkodralake.al

Keywords: biodiversity conservation, ecosystem services, Shkodra lake, community based, action planning

Ten years of winter reed cutting in Rozwarowo Marshes (Poland) - effects on vegetation and breeding birds

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Rozwarowo Marshes are a Natura 2000 site and are located 15 km from the Baltic Sea, between Kamien Pomorski and Wolin (NW-Poland). Grzybnica river devides the peatland into two parts and flows to the Baltic Sea. Water levels are largely artificially managed by three landowners managing the site, mainly for winter reed cutting. The peatland is c. 7 km long and 3 km wide and is surrounded by agricultural land and some forest. The site is famous for rare mire species such as *Myrica gale* and *Carex pulicaris*, but also halophytes and especially for the globally threatened Aquatic Warbler (*Acrocephalus paludicola*). Rozwarowo Marshes are the last stronghold of its "Pomeranian population". We have studied vegetation and breeding birds, especially Aquatic Warblers, in Rozwarowo Marshes since 2005. The poster presents data on vegetation composition, vegetation structure, breeding bird community, and Aquatic Warbler distribution in the light of mowing (mainly winter reed cutting, occasionally summer mowing), hydrological regime and nutrient conditions. It is assumed that winter reed cutting can maintain plant species diversity and Aquatic Warbler habitats as long as trophic conditions remain stable. In recent years, very nutrient-rich water (fertilisers, decomposing peat) is brought to the site, especially from channel Rozwarowo (from some 5,000 ha intensively farmed land, partly drained peatland). Eutrophication has probably caused rapid Aquatic Warbler habitat deterioration despite of the implementation of previously suitable management. Since 2016, a conservation project implements urgent measures to reduce nutrient loads.

Keywords: reed, thatch, Natura2000, Aquatic Warbler

Ten years of summer conservation mowing in Peene Valley (Germany) - effects on vegetation and breeding birds

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The Lower Peene Valley is a large peatland east of the city of Anklam. Large parts are Natura 2000 sites and nature reserve. Most of the area has been used for low-intensity mowing over centuries. Several former polders have been rewetted in the last decade and are flooded.

In parts that have never been deeply drained, summer mowing for conservation has been reintroduced since 2005. At that time, the main focus was to restore habitat of the globally threatened Aquatic Warbler (*Acrocephalus paludicola*). Within a Polish-German LIFE project (2005-2011), some 150 ha have been annually mown and monitored, and use options for the reed and sedge biomass have been explored. We present outcomes on vegetation composition, vegetation structure, breeding bird community, and Aquatic Warbler distribution in the light of mowing (summer conservation mowing), hydrological regime, and nutrient conditions. Floristic composition indicates a slow change from species-poor, dense reeds to more open, and species-rich sedge-reed vegetation. Summer mowing can create suitable habitat conditions for waders such as Redshank (*Tringa totanus*) and Lapwing (*Vanellus vanellus*). Using biomass from conservation mowing in remote peatland areas remains a challenge.

Keywords: conservation mowing, vegetation, waders, biomass use

Impact of *Sphagnum*-harvesting on invertebrates: species composition and habitat changes on a donor site in northwestern Germany

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New approaches of peatland restoration and Sphagnum farming are based on the introduction of peat mosses. The objective of this survey was to analyze the effects of *Sphagnum* harvesting on invertebrates and their habitats on donor sites in/near natural peatlands. Peat mosses were harvested manually on 1 ha of a raised bog remnant near Papenburg (Germany), in autumn 2015. From May to August 2016 dragonflies (*Odonata)* and butterflies (*Lepidoptera*) were surveyed and harvested on control plots. In addition, vegetation surveys were conducted. Invertebrates living in and on the upper moss layer were studied by manual extraction of peat moss samples.

The results show significant differences between fauna and vegetation on the harvested and control sites. On the control sites the dragonfly *Enallagma cyathigerum* and the butterfly *Plebejus argus* were more abundant and more invertebrates were collected in the upper moss layer. However, the analysis did not reveal any clear differences regarding the number of species between the sites. The *Sphagnum* harvesting has significantly reduced the average height of ericaceous strata and moss strata as well as the average cover of ericaceous strata. This loss of shelter and flowering nectar probably reduced the abundance of dragonflies and butterflies. Our results show that *Sphagnum* harvesting has changed habitat structure and invertebrate abundance only to a small extent, without effects on species numbers. We conclude that careful and manual *Sphagnum* harvesting has only a minor impact on donor sites.

Keywords: *Sphagnum* harvesting, raised bog, invertebrates, biodiversity, Lower Saxony

The ecological monitoring of vegetation of mires of Belarus: structure, methods, network points.

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Until the sixties of the last century, natural peatlands in the Belarus occupied an area of 2.39 million ha (11,5% of the country). Now the total area of 863 thousand ha, or 4.2% of the territory (Strategy of sustainable use of peatlands, 2015). Most of the mires are drained and used for industrial (peat mining), agricultural, and forestry purposes. Since the late 90‘s there has been organised target monitoring of flora and fauna at a number of mire areas. But due to the global loss of the mire ecosystems we proposed a comprehensive environmental monitoring of mires throughout the country. The subject of monitoring are plants, plant communities (phytocenoses) and the medium of their existence (edaphotope) both natural and drained mires, peatlands and secondary waterlogged territories. It highlighted two structural monitoring units:

1. Monitoring the vegetation of natural mires, which in turn is divided into: a) monitoring of vegetation of eutrophic mires, b) monitoring of vegetation mesotrophic mires, and c) monitoring of vegetation of oligotrophic bogs;
2. Monitoring the vegetation of drained mires and secondary waterlogged territories, which is also divided into: a) monitoring of vegetation on exhausted peatlands b) monitoring of vegetation of renewable mires, and c) monitoring of agrophytocoenoses on drained lands.

The units have dedicated monitoring, reflecting the nature of the observations: phytocoenotic, floristical, phytopotological, edaphical (incl. control of CO_2 and CH_4 balance) and others.

Integrated point of observations of vegetation and soils of mires is a key sight (KS). Points of direct observation – a permanent sample plot (PSP), located on KS through eco-phytocoenotical profile, or transects. Preliminary monitoring network of mires consists of 48 KS and 250 the PSP. Extensive monitoring of the main, natural, and anthropogenic impacts is localized at 6 monitoring polygones located in different geobotanical subzones of the country.

Keywords: bog vegetation, ecological monitoring, Belarus

Phragmites australis niches for other biota are similar on three continents

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Common reed (*Phragmites australis*) is one of the most widely distributed, most abundant, and best-studied vascular plants worldwide, but there has been no broad comparative analysis of reed-associated biota on different continents. A survey of observational data on (mostly terrestrial) organisms using *P. australis* reedbeds revealed ecological parallels among North America, Europe, and sub-Saharan Africa. I present examples for a selected group of 27 niches (i.e., features of the reed plant or reedbed used in particular ways by groups of organisms). Niches include animals eating particular portions of reed, birds roosting in reedbeds, and vines using reeds for support. These similarities in habitat functions in bioeographically distinct world regions suggest a fundamental character of reed ecological relationships related to the large size, extensive stands, high productivity, deep litter layers, and other traits of reed. The data also underlines the biodiversity support functions of reed and their similarity among continents. Managers can consider reed niches and user guilds to design management approaches and predict outcomes of conservation, management, or other environmental changes affecting reedbeds, whether native or introduced, over-abundant or under-abundant.

Link: hudsonia.com

Keywords: Community convergence, ecological equivalents, marshes, moulting habitat, reedbed, roosting habitat

Large-scale plant micropropagation

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Since the 1960s the development of plant tissue cultures techniques have played an important role in various scientific and industrial fields. However, traditional in vitro plant growing methods, using small glass or plastic containers (e.g. jars), possess crucial limitations such as a low amount of cultivation medium, an inefficient gas exchange, or a premature culture ageing. All of which may cause up-scaling breeding close to impossible or at least significantly increasing utilisation of material and human resources. The construction of high-yielding plant cultivation systems has become a matter of great importance, not only for pharmaceutical and agricultural industries, but also for scientific fields such as the plant conservation and reintroduction. Hereby, we present a novel utilisation of a commercial, large-scale plant-breeding bioreactor, which has been adopted to multiply peat moss (*Sphagnum* sp.), biomass, and sundews plants (*Drosera* sp.). Peat moss, under optimum condition, is relatively fast-growing.

We have also studied the systems efficiency and plants physiological condition in comparison to standard methods previously used in PSTP Laboratory: the agar medium and suspension cultures. The fresh biomass of *S. cuspidatum* grown in the TIS and the suspension culture.

Keywords: *Sphagnum*, *Drosera*, Temporary Immersion System, peatland recultivation

CLEARANCE project: CircuLar Economy Approach to River pollution by Agricultural Nutrients with use of Carbon-storing Ecosystems

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Riverine wetlands provide a range of ecosystem services: cultural (esthetics, recreation and education), provisioning (storage and retention of water), supporting (soil formation and nutrient cycling), and regulating (regulation of erosion, natural hazards, hydrological flows, climate, water purification and waste treatment). The project CLEARANCE focuses on the role of wetland buffer zones (WBZ) in agricultural catchments that clean water from excess nutrients before it reaches the river, as well as substantially contribute to the natural purification of river water. The project aims to demonstrate this role of WBZs using model catchments, while at the same time examining synergies between water purification and other ecosystem services, including paludiculture, i.e. economic utilisation of wetland plants.

The key concept of CLEARANCE is to enhance multifunctional use of riverine wetlands via circular economy, where nutrients captured in wetland biomass are re-used to produce energy (via combustion, biogas or pyrolysis), materials or soil substrates (compost), while at the same time reducing greenhouse gas emissions via rewetting of drained organic soils and re-establishment of peat formation. Last but not least, riparian biodiversity and recreational functions of riverine wetlands are treated as co-benefits of the above-listed services, altogether allowing for a multi-faceted evaluation of WBZs and developing an integrated framework - socio-economic, environmental and political - for the implementation of WBZs in circular economy.

CLEARANCE will deliver: (1) assessment of synergies and constraints between nutrient removal in WBZ and biomass utilisation; (2) analysis of market and non-market values of rivers and river ecosystem services (as co-benefits of WBZ); (3) quantification and upscaling of costs and benefits of WBZ at the catchment scale; (4) policy and social network analysis concerning feasibility of using WBZ in circular economies as a solution to agricultural nutrients pollution; (5) market assessment of commodification options of WBZ-related ecosystem services, including nutrient removal and biomass production.

Keywords: paludiculture, riparian wetlands, wetland buffer zones, ecosystem services

Irrigation control system for the production of *Sphagnum* biomass: Tracking of water consumption

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Sphagnum farming is the production of undecomposed *Sphagnum* biomass under a sustainable and renewable approach. This technology allows for the production of alternative substrates to natural blond peat. For the production of *Sphagnum* biomass water management is one of the most important items. The objective of this project was to know the water consumption needed to maintain groundwater level in residual peatlands. This project was carried out in a peat bog where peat had been extracted using the block cut method, located at Shippagan (New-Brunswick, Canada). Six experimental basins of approximately 1000 m^2 were established for the production of *Sphagnum flavicomans, Sphagnum magellanicum, Sphagnum rubellum*, and *Sphagnum fuscum*. For the configuration of each basin, three types of irrigation channel (peripheral, on the short side and on the long side) and two set points (-10 and -20 cm) for the water tables were taken into account. This system operated pumps to supply water to the irrigation canals to increase the water table within the basin. The water consumption is proportional to the length of the irrigation channel. The system developed in this project can be implemented for peatlands that are far from urban areas, since the system was powered by solar energy. Irrigation optimization will be the objective of further works by combining the control structure of the irrigation system with numerical analysis methods and meteorological information.

Keywords: biomass production, Sphagnum farming, post-extraction peatlands, groundwater

Potassium status after 17 years of wet grassland restitution on a degraded minerotrophic peat soil

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There is a broad consensus that the fate of nutrients in rewetted peatlands is of major concern in restitution ecology, due to its various influences on ecosystem functioning. In contrast to the macronutrients N and P, potassium (K) has received comparably little attention as K effects on water quality are not as detrimental as those of N and P. However, K plays a decisive role in plant growth on peat soils and is especially important when the aim is to produce notable quantities of biomass like in paludiculture and wet grassland farming.

We investigated the dynamics of plant available soil K (KDL) in the topsoil of 52 grassland sites in the “Osterfeiner Moor”, a polder of 180 ha north of Osnabrück (Lower Saxony, Germany), during a time period of 17 years, starting in 1999, after rewetting.

The focus is on explanatory variables for the varying K contents at the differently managed sites. Pre-winter soil sampling and analysis of plant available potassium (double-lactate extraction, KDL) were repeated in 2003, 2005, and again in 2016 to elucidate the long-term effects of prohibited fertilisation and restricted management implemented in order to pursue nature protection goals.
KDL topsoil contents decreased from initial levels of 7-32 mg 100 ml^{-1} in 1999 to 8-22 mg 100 ml^{-1} in 2016. While the use of these peat soil grasslands had a significant effect on KDL (0-10 cm) contents, other factors were found to only partly contribute to the explanation of the differing K-budgets. Considering both the amount of peat-derived potassium from mineralisation processes, and the reported leaching of K from similar soils, we had expected a stronger decrease in KDL contents than we actually found.
Keywords: potassium, grassland use, low peat, resurvey

Processes and efficiency of nitrate turnover in degraded peat under continuous flow conditions

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Constructed wetlands (CW) may provide favorable conditions to remove nitrate from polluted agricultural runoff via heterotrophic denitrification. Although the general operability of CW has been shown, it remains unclear if peat soils are suitable as a bed medium for a vertical flow-through reactor. A long-term flow experiment was conducted in a mesocosm aiming at quantifying nitrate turnover efficiency in peat soils. Nitrate was applied at three different concentrations (65, 100, and 150 mg l^{-1}). Pore water samples were collected and analyzed for NO_3-, SO_4^{2-}, pH, dissolved CO_2, CH_4, and N_2O, respectively. The redox potential (Eh) was measured at different depths to determine the spatial distribution of denitrification favorable zones. In addition, the temperature and flow conditions were monitored during the whole experiment. The results show that nitrate removal efficiency is affected by hydraulic and environmental boundary conditions. The highest nitrate removal efficiency occurred when the nitrate was applied at 100 mg l^{-1} with a lower flow rate, higher temperature and thicker redox potential zone (Eh<150 mV). The observed increase in SO_4^{2-} near the bottom of the experiment container implies a sulfur oxidation although redox conditions would suggest a sulfur reduction. We assume that in soil zones with a very low redox potential iron disulfide may occur which might be oxidized to SO_4^{2-}. Thus, degraded peat soils have the potential to serve as a substrate for the clean-up of nitrate-laden agricultural runoff.
Keywords: constructed wetlands, degraded peat, nitrate turnover efficiency

Hydraulic conductivity of coastal fen peat as influenced by salinity

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Pore water chemistry can affect the hydraulic properties of mineral and organic soils, which can be relevant for the management and cultivation of these soils. In previous studies, on bog peat, an increase of the saturated hydraulic conductivity (Ks) due to a pore dilation effect induced by a moderately increased water salinity was observed. In this study, we are aiming at quantifying the impact of higher salinities (up to 3.5 %) on Ks of fen peat, in order to evaluate its impact on the water flow and solute transport especially in coastal peatlands. Two approaches differing in measurement duration employing a constant-head upward-flow permeameter were conducted. At first, Ks was measured at an initial salinity for several hours before the salinity was abruptly increased, and the measurement continued. In the second approach, Ks was measured for 15 min at the salt content observed during sampling. Then, samples were completely (de)salinized via diffusion for several weeks before a comparison measurement was carried out. The results for degraded fen peats show a decrease of Ks during long-term measurements which does not depend on the water salinity. A slow diffusion-controlled change in salinity does not modify the overall outcome. The duration of measurements has a stronger impact on Ks than the salinity. Further experiments will show if fen peat soils differing in their state of degradation exhibit a different behavior. A preliminary conclusion is that salinity might have a less important effect on hydraulic properties of fen peat than it was observed for bog peat.

https://www.baltic-transcoast.uni-rostock.de/

Keywords: peat, salinity, Saturated Hydraulic Conductivity

The fate of nitrogen originated from mown wetland biomass in a swampy river valley landscape

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Anaerobic digestion of plants mown in order to restore the species compositions of wetlands is a promising option that can solve the problem of harvested biomass management. To identify the pathways of nitrogen from biogas residues applied to the arable soils in the landscape of swampy river valley the incubation experiment was run using arable soil typical for the region and four digestates from anaerobic digestion of the following plant species mown in wetlands located in the Narew River Valley, Poland: *Glyceria maxima, Phragmites australis, Carex elata* and *Phalaris arundinacea*. The amount of N in all digestates was similar and ranged from 0.266±0.11% (ww) to 0.294±0.031% (ww).

The inorganic N concentration ceased in soil during two first weeks of incubation, mainly due to a reduction in NH_4-N and after immobilization period fast NO_3-N production started, leading to almost double amount of NO_3-N as well as inorganic N in fertilized soils comparing to unamended one. At a landscape scale, the incorporation of nitrogen from biomass harvested in the wetlands into the soils on the adjacent arable land can play an important role in nitrogen cycle in a swampy river valley landscape by being effective at reducing the transfer of nitrogen from upland arable soils to the river through the decrease of additional nitrogen input from synthetic fertilizers.
Keywords: nitrogen, anaerobic digestion, digestate, Narew River Valley

Paludiculture – risks, chances, positions and needs for action from a nature conservation point of view

Position paper by German Federal Agency for Nature Conservation and Agencies for Nature Conservation of the federal states rich in peatlands

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In Germany more than 95 % of the peatlands are drained and cause about 5 % of the total German greenhouse gas emissions. Although only about 6 % of the agricultural area is located on peatland, emissions from none-adapted peatland-use account for about 54 % of greenhouse gas emissions originating from agriculturally used soils. Agriculturally used peatlands accordingly possess a high potential for saving greenhouse gas emissions.

A complete rewetting of peatlands and abandonment of all use on these sites would be the most effective measure reducing greenhouse gas emissions caused by agricultural utilisation. However, this is unrealistic with regard to the total peatland area. In consequence, a comprehensive adaptation of the existing land-use, usually in combination with the raising of the water level, is urgently needed for reasons of climate and biodiversity protection.

Currently, traditional types of land-use on peatlands with a high water level like wet grassland use or reed cutting for roofing are of little importance in quantity. Hence, alternative types of wet peat- and climate-friendly land-use have been invented as well as promoted within the last years under the label “paludiculture”. Their establishment in practice contains opportunities and risks for nature conservation.

For this reason the German nature conservation agencies, of the federal states rich in peatlands, together with the Federal Agency for Nature Conservation, have elaborated a position paper on paludiculture, which is presented in this poster. The position paper points out the chances, risks, positions, and needs for action and for further research connected with paludiculture from a nature conservation point of view. Chances and risks intrinsic to different types of paludiculture should be taken into account before the framework conditions set up by agricultural policy, public funding, and legal regulations are adapted in order to render paludiculture into an economically viable true alternative land-use.

Keywords: biodiversity, agriculture, risk analysis, suitability area, policy adaptation

Could there be paludiculture on Finnish cultivated peat soils?

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In Finland, emissions of carbon dioxide and nitrous oxide from cultivated peat soils consist 10% of the national total and 60% of agricultural greenhouse gas emissions.

They are the most promising target for mitigating actions but, the past and current agri-environmental measures have not attracted farmers to change the way peat soils are cultivated.
Paludiculture has not been implemented in Finland, but controlled drainage on peat soils is being supported by environmental payments. Based on the current research, it seems that controlling the water table is so difficult that it is almost impossible to implement it successfully, while also getting both satisfying yields and GHG mitigation. This points to the direction that total rewetting is a more realistic and definitely more efficient option to minimize the emissions. The obstacles of implementation are 1) loss of agricultural subsidies with the new crops, 2) lack of machinery for wet conditions, 3) lack of markets for the new products, and 4) prejudices. We plan to start projects to study the practical implementation of paludiculture as a greenhouse gas mitigation measure on cultivated peat soils.
We propose that for the best environmental benefits the environmental payments should be targeted to deep peat soils and the sum per hectare should be higher than currently available. Regionally targeted measures and cooperation of farmers could be used to realize the potential of GHG mitigation with paludiculture. Based on a regional mapping exercise, we will present a calculation showing the potential of paludiculture to reduce these emissions. We will ponder the benefits and barriers of implementation as well as the feasibility of new crops and suitability of the available emission factors for reporting the GHG impacts of paludiculture.
Keywords: cultivated peat soils, paludiculture, GHG emission, policies

Review on economic incentives for wet peatland management

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The Food and Agriculture Organisation of the United Nations (FAO) supports paludiculture as an option for the responsible management of peatlands and identifies six actions for achieving large-scale paludiculture. Major importance is assigned to the development of incentives that account for the social and environmental benefits of paludiculture.
Our review compiles economic incentives and instruments that already exist in different European countries (e.g. Germany, Netherlands, Sweden, UK) that may be used to support the implementation of agriculture on wet peatlands. Incentives as payments for ecosystem services represent the changed societal demands, they may initiate and reward the shift to sustainable peatland use and increase the economic viability and competiveness of paludiculture. Four different sources of financing are identified: a) government financed instruments as agri-environment- and climate measures within the 2nd pillar of the EU Common Agricultural Policy (CAP) or national payment schemes for nature management, b) compulsory measures compensating building or mining activities financed by enterprises, c) taxes, levies, charges, and d) instruments such as voluntary markets for ecosystem services

allowing for private sector or private persons investments. Payments can support investments, reward measures or remunerate results. Incentives can focus on any point of the production chain including rewetting, establishing of paludicultures, management, biomass processing, and marketing of products including the provision of specific ecosystem services.

We present our preliminary analyses and selected examples. Furthermore, we are looking forward to meeting interested participants of the conference in order to learn about experiences in different countries and discuss recommendations for incentives to encourage paludiculture.

Keywords: agri-environment- and climate measures, payments for ecosystem services

Physical and chemical properties of organic soils under agricultural use in Europe

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Organic soils offer numerous functions from the global to the local scale; they constitute the biggest terrestrial carbon storage on the globe, form important nutrient filters for catchments and provide hydrological buffer capacities for local ecosystems. Cultivated organic soils, however, show extreme mineralisation rates of the organic substance and turn into hotspots for green house gas emissions, which are highly vulnerable to land surface subsidence, soil and water quality deterioration and thus crop failure.

The aim of this study is to analyse the impact of past agricultural management on soil physical and chemical functions of organic soils in six European countries. We conducted standardized soil mapping, soil physical/chemical analysis, ground water table monitoring and farm business surveys across 7 to 10 sites in Germany, The Netherlands, Denmark, Estonia, Finland, and Sweden.

The results show the strong impact of past agricultural management on soil functions across Europe. Organic soil under intensive arable land use consistently offers the lowest bearing capacities in the upper 10 cm compared to extensive and intensive grassland use, which is a major limiting factor for successful agricultural practice on organic soils. The difference can be explained by root mat stabilisation, since soil compaction in the upper 25cm is highest under arable land use. A strong decrease of available water capacity and saturated hydraulic conductivity is consequently observed under arable land use, further intensifying hydrological problems. Soil carbon stocks clearly decrease with increasing land use intensity. The highest carbon showed stocks on extensive grassland. This is supported by the degree of decomposition, which is lowest for extensive grass land. Overall, findings indicate a strong impact of land use intensity and management on soil carbon losses and peat degradation on the European scale.

Keywords: organic soil, peat, agriculture, chemical properties, physical properties

Mapping and monitoring of Sphagnum farming site with ultra-high resolution UAV- and ground-based imagery

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Imagery aquired by Unmanned Aerial Vehicles (UAVs) provides several advantages over conventional satellite and aerial imagery. For instance, under suitable weather conditions, images can be recorded at any given date (e.g. simultaneously with field work), with short revisit times, at much higher resolutions and often with less overall financial investment. Acquisition of ground-based imagery is even easier to implement due to lower requirements in terms of cost, training, and weather. Thus, there is a high potential for mapping and monitoring sites with high accuracy at relatively low expenditures.

In this ongoing study we investigate the suitability of different approaches of mapping and monitoring of a large-scale Sphagnum farming test site (approx. 15 ha) in the "Hankhauser Moor" in Lower Saxony, Germany. The UAV-based imagery we acquire with both a custom-built quadcopter and hexacopter, whereas ground-based imagery is acquired from preferably at least slightly elevated points around the studied site, both in conjunction with ordinary and differential GPS.

Preliminary results show that, in principle, both types of imagery can be used to derive detailed orthomosaics as well as digital surface models (DSMs) for further analysis. However, UAV-based imagery is more suitable if remote sensing methods are to be applied due to the surface reflection being captured from above. It also provides generally higher accuracies and larger areas can be covered in less time. Depending on acquisition altitude and camera, the imagery's horizontal resolution varies from centimeters to millimeters per pixel, vertical accuracy is potentially in the sub-centimeter range. By using supervised and object-based classification algorithms, *Sphagnum* moss can be differentiated from bare peat and other plants which enables e.g. the evaluation of plant growth after establishing Sphagnum farming sites. The differentiation between other plant species as well as the estimation of *Sphagnum* vitality and moisture content is still being studied.

Keywords: UAVs, photogrammetry, remote sensing, ultra-high resolution imagery, paludiculture, Sphagnum farming

A concept for using unmanned aerial vehicle mapping and ground penetration radar to map peatland structures as a planning tool for peatland rewetting and paludiculture.

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The use of ground penetration radar (GPR) to map peat depth and stratigraphy is a widely applied method offering a quick and easy way to collect data.

Combining this data with digital elevation models which can be derived by aerial triangulation of ultra-high resolution images obtained by unmanned aerial vehicles (UAV) can offer a comprehensive picture of the structure of peatlands.
When planning peatland restoration projects and implementing paludiculture, e.g. Sphagnum farming, detailed knowledge about the surface and peat stratigraphy is necessary.
GPR is widely used in peatlands stratigraphy researches (Warner et al. 1990, Proulx-McInnis et al. 2013, Dallaire & Garneau 2008, etc.), peatland origin researches (Comas et al. 2011 etc., Kettridge et al. 2012), measuring hydrological properties (Huisman 2003, Lowry 2009, etc) helps with gas emission estimations (Comas et. al. 2005, 2007, Parsekian et al. 2011), peat volume estimation (Parsekian et al. 2012 etc). But there are lack of researches using GPR for degraded peatlands (Bricheva et al. 2017). On the contrary UAV is widely used in degraded peatlands researches (Knoth et al. 2013, Grand-Clement 2015, etc.)
The feasibility of combining GCP and UAV has been demonstrated (with a different focus) in a small peatland site in Arkhangelskaya oblast, Russia. We used a cheap consumer grade multicopter (SKYCAP UAV) equipped with a GoPro Hero3 camera to retrieve air-borne images. A GPR – Zond 12e advanced with shielded antenna 300 Mhz was used. Velocity of the electromagnetic waves was determined by peat stratigraphy researches using Russian peat core. The UAV processing resulted in image mosaic with 3 sm spatial resolution.
Detailed UAV mapping shows water ability, saturated peat, type of vegetation, condition, with high precision level. Map of different peat layers can be generated by GPR data processing including different decomposition, density, structure, water quality and ability.
Combined data is a base for the recommendations how much peat should be removed to get a flat area, how much peat should be removed to get a peat surface with homogenous properties for Sphagnum farming, where to place walls etc.
Hence, the results of the work show potential of the combining GPR and UAV data for fast researches of the wetlands for biomass growing too.
Keywords: peatland, ground penetration radar, unmanned aerial vehicle, rewetting planning

Long-term changes in plant productivity, nutrient status, and vegetation development at a simulated common reed meadow – An outline for a long-term paludiculture field trial

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The intensification of land use and drainage of peatlands has accelerated peat loss over time, leading to the limits of economically reasonable peatland use in northern Germany.

Recently a variety of climate change mitigation strategies for peatlands have been discussed. As the most effective measure the rewetting of thick fen mires has been carried out since the mid-1990s. Since rewetting excludes conventional agro-engines due to weak peat soils the concept of paludiculture, the cultivation of wet soils, is a promising option of adding value. However, the long-term effects of paludiculture on GHGs, C balance, nutrient status, and vegetation composition are unknown, because field trials have only recently been conducted (usually covering two years or less). Therefore, we aim to test the long-term applicability of common reed as a pilot paludiculture crop in a long-term field trial.

Our goal is to examine to what extent removing emergent macrophytes as paludiculture crops alters the ecosystem productivity, the nutrient supply, and possibly induces a vegetation shift. In addition, we want to test if fertilisation (in forms of biogas residues, reed ashes, or mineral fertiliser) counteracts possible vegetation shifts. During the last years of the field trial, full GHG balances should be measured. We assume, that this allows us to give profound concepts for site-adapted peatland reed management.

Here, we discuss a factorial block design with harvesting and fertilization of different intensities needing homogenous site characteristics. Since reed stands are permanent pastures the design would be simplified due to a lacking crop rotation. Reeds are able to exploit relatively far nutrient sources through their strong capability of extensive lateral root growth. Therefore, the suggested minimum parcel size is 5 x 3 m with an edge effect buffer of 3 m. Since reeds have a low mowing capability, we suggest 1 to 2 harvests per year and three fertilisation equivalents of 0 / 90 / 180 kg N ha^{-1} plus an unharvested/untreated control. Thus, the seven treatments with four replications could be carried out on less than 0.2 ha.

The experiment would need to be fenced to avoid disturbances through deer or wild boars. Water-table monitoring should run continuously at the edges and in the middle of the field trial (five groundwater pipes). Plant species composition should be determined at the end of July every year using the scale for cover-abundance estimation. Biomass should be harvested in the whole parcel, with dry matter, C and N content determined estimating their export from the system. Topsoil organic matter, C, N, and P should be measured annually from every parcel at the end of the non-growing season to account for long-term nutrient state changes. A profile based C storage estimation could be carried out within each treatment at the beginning and the end of the experiment, with sampling depth reaching the mineral soil to account for bulk density changes as well as changing decay rates of the acrotelm during plant succession and nutrient states changes.

Keywords: peatland restoration; mire conservation; peatland use; minerotrophic fen

WETSCAPES –from understanding to sustainable use of peatlands

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Peatlands and coastal wetlands are characteristic elements of the landscape and, thus, of land use in Mecklenburg-Western Pomerania. Depending on water and land management, their possible contribution to climate and water protection is much higher than that of other ecosystems. The aim of WETSCAPES, an interdisciplinary joint project of the Universities of Greifswald and Rostock, is to develop scientific principles for sustainable and gentle cultivation of former degraded and now rewetted peatlands. WETSCAPES provides the basis for a nationwide, internationally influential research and development structure, spanning the biogeochemical complex of primary production, metabolic processes, matter transport, gas exchange, and peat formation at wetlands. It builds on existing structures at the Universities of Greifswald and Rostock and integrates them over other universities and institutes (DLR, LIKAT) with the goal to understand ecosystem interactions (upscaling) and to derive indicators for sustainable management. It integrates joint research at six central investigation sites and one complex central experiment with a unique fen lysimeter. Mecklenburg-Western Pomerania will benefit from the development of scientific based, sustainable and innovative utilisation, from value chains in agricultural production and sustainable tourist use of fragile peatlands and coastal sites, which will be optimized or newly developed considering the aims of environmental protection and nature conservation. The project is funded within the excellent research program of Mecklenburg-Western Pomerania with 5 million Euro from 2017 till 2021 with means of the European Social Fund.

https://www.wetscapes.uni-rostock.de/

Keywords: peatlands, cultivation, paludiculture, ecosystem understanding

Excursion Overview

Excursion 1: Vegetation, greenhouse gas balance and biomass use on rewetted peatlands in the Peene River valley

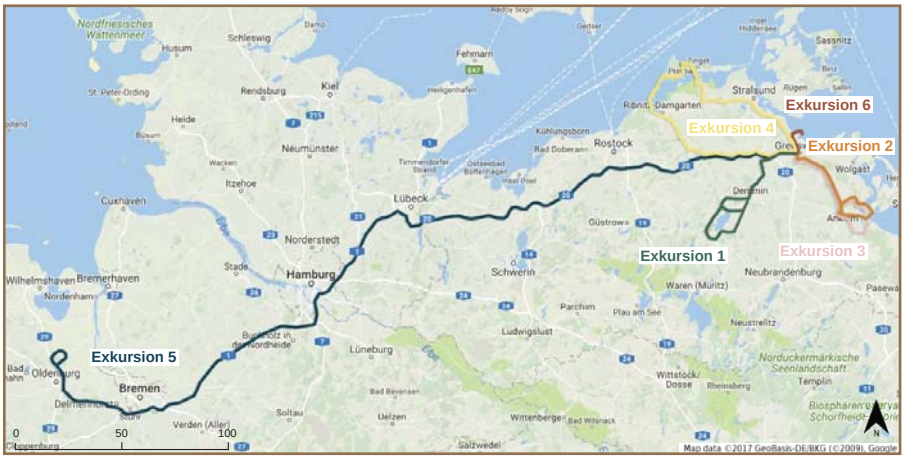
Excursion 2: Land use history, mowing machinery and biomass use for building material at Peene river mouth

Excursion 3: Peatland rewetting, land use and birds in Lower Peene river valley

Excursion 4: Peatland research on mown and grazed rewetted peatland in Recknitz and Trebel river valleys and on Darss peninsula

Excursion 5: Paludiculture on rewetted bogs near Oldenburg

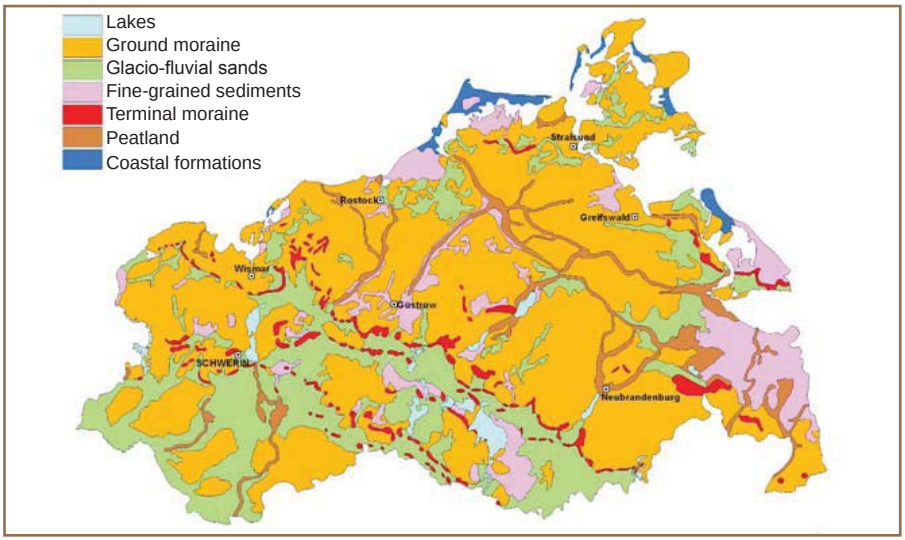
Excursion 6: Paludiculture plants and salt meadows near Greifswald



Outline map of the excursion routes

General information for the excursions in Mecklenburg-Western Pomerania

Bedrock and relief



Geological formations of Mecklenburg-Western Pomerania.
Source: https://www.lung.mvregierung.de/images/karte_q.jpg

The federal state Mecklenburg-Western Pomerania extends along the Baltic Sea coastal plain and is situated in the North of Germany. Its hinterland stretches southward to the lower Elbe River in the West and beyond the sources of the Havel River and nearly to the Oder River in the East. Most of Mecklenburg-Western Pomerania drains into the Baltic Sea. The moderate climate is primarily influenced by the Atlantic Ocean and Baltic Sea. The region's landscape was largely formed by glacial forces, which deposited materials and shaped the scenic hilly sites and lowlands that filled during the Holocene after the melting of the ice of the late glacial period of the Vistula ice age (since ~ 11.000 years before present) with wide peatlands, lakes, and meandering streams. At present nearly two-thirds of the state are used for agriculture and about one-fifths by forest.

The central part of Mecklenburg-Western Pomerania is traversed from west to east by a hilly plateau with fertile clay soils covered by beech forests. The Southwest, between the plateau and the Elbe river, has poor sandy soils, pine forests, and marshy valleys. Along the coast, steep cliffs alternate with beaches and dunes. Western Pomerania has two coastal national parks: The National Park "Western Pomeranian

Boddenlandschaft" is situated largely on the Darss Peninsula and its surrounding waters, and the National Park "Jasmund" on the northeastern coast of the island Rügen (Duphorn et al. 1995).
In the younger past agriculture was the main driving sector that shaped the landscape in Mecklenburg-Western Pomerania. During the GDR era (1945–90) collectivation programme merged small private farms into large state owned collective farms ("Landwirtschaftliche Produktionsgenossenschaften", LPG). After the German reunification (1990) and privatization of farms, these, for German and Western European standards relatively large-scale structures in agriculture, continued to prevail. This, on the one hand side, helped to maintain and develop the competitiveness and efficiency of agriculture as an important economic sector in Mecklenburg-Western Pomerania, but on the other hand side also exacerbated environmental problems that were induced in the 1960s with a large-scale programme for land reclamation and drainage of peatlands - the "Komplexmelioration". Currently the main cultivated crops are wheat, barley, sugar beets, potatoes, rye and grass. Corn (maize) and peas are also grown, and the state is among Germany's leading producers of rapeseed. The region's pastures, mainly on drained peatlands, support herds of cattle, sheep and horses.

Peatlands in Mecklenburg-Western Pomerania

In Mecklenburg-Western Pomerania peatlands cover 12% (about 290,000 ha) of the land area. The majority is currently drained for agricultural purposes. These soils cause 27% of the total CO_2 emissions of the federal state. Less than 3% of the peatland area are under near natural or undrained conditions, another 59% are extremely or strongly degraded by drainage. Peatland drainage measures of the "Komplexmelioration" were implemented till the early 1980s. But fertility and capillary water conductivity dramatically decreased under intensive agricultural use on drained peatlands, so that a peatland conservation movement started in the 1990s and led to the federal programme for peatland conservation of Mecklenburg-Western Pomerania in 2000. Since then on 26,032 ha of peatlands (8.9 % from the total peatland area), measures for rewetting and stabilisation of the hydraulic conditions have been implemented.
Most widespread are river valley peatlands. Pristine river valley peatlands consist of three adjacent and functionally connected ground and surface water fed hydrogenetic mire types from the edge of the river valley to its center: close to the surface spring mires, in the valley plain percolation mires, and adjacent to the river flood mires.
Spring mires are fed by ground water, they develop where aquifers are truncated and therefore artesian ground water continuously discharges to the surface. Spring mires are sloped sometimes even forming small cupolas and ridges. Where the artesian ground seeps out with high pressure calcium is precipitated; the peat is highly

decomposed and shows a high calcium content. In the Peene valley, spring mires can be found e.g. near Loitz (Quellkuppe Loitz).
Percolation mires stretch across the sloped river plain adjacent to the spring mires. They are fed by the spring mire water discharge and continuously ground water inflow therefore the peat is only slightly decomposed and mineral and nutrient contents decrease to the center of the valley until the flood water regime of the river overrules the groundwater flow. The hydraulic conductivity of the peat body is high, and surface water levels are stable due to continuous water supply and the oscillation capacities of the slightly decomposed peat body. Percolation mires are the dominant peatland type of the North-Eastern German Plain. In the Peene catchment area percolation mires developed due to a high ground water influx from the edge of the river valley and increasing backwater due to the postglacial eustatic sea-level rise of the Baltic sea in the region.
Flood mires are under the influence of water from neighbouring water bodies. They are inundated periodically or episodically and can also fall dry. This mire type only occurs where inundations regularly occur. Inundation mires can be found in parts of the "Große Rosin" at the Kummerow lake and in the Lower Peene valley, downstream of Anklam. The periodically occurring dry periods provoke the development of highly decomposed peat and eutrophic nutrient conditions.
Locally bogs (ombrotrophic mires) can develop in river valley complexes where precipitation water forms rainwater lenses nesting in groundwater fed fen areas. The "Anklamer Stadtbruch" has 500 ha of such bog area nesting in a percolation mire. It is the biggest bog complex in Mecklenburg-Western Pomerania but unfortunately widely destroyed by peat extraction.

The Peene river valley

The Peene river valley is a former meltwater valley in the extended flat ground moraines of Mecklenburg-Western Pomerania. It stretches over 85 km from Lake Kummerow (Kummerower See) in the west to the Oder Lagoon (Oderhaff) in the east. After the Elde River, the Peene River has the second largest catchment area and discharge of all rivers in Mecklenburg-Western Pomerania. It has an extremely small hydraulic gradient of only 20 cm over 85 km. When water levels in the Baltic Sea are high or when strong winds blow from the east, an unusual phenomenon can be observed: the Peene River flows upstream.
The Peene river valley belongs to the system of the large river valleys of northeastern Germany. By autonomic peat growth (Kulzcinsky 1949) extensive percolat on mires formed, with peat deposits of more than 9 m thick, fed by calcium rich groundwater from the mineral ridges (Succow 1971).

The minor inland glacier dynamics during the Vistula ice-age left a relief-poor area behind. There are no large jolted end moraines and deep exaration basins. Therefore, the occurence of deep lake-filled hollow basins is very restricted. The inland glacier was fragmented in smaller parts due to the gradual rewarming when the defrosting held on for a longer time. Repeated thrusts and retreats of smaller ice-glaciers poured shallow end moraines in intermediate steps. According to Janke & Reinhard (1968) the sand inclusions in the Peenearea, caused by refrosting, were to no extent comparable to those areas south of the main end moraine of the pomeranian stage. The drainage of the remained glaciers was more 'line-like' through meltwater tracks, the primary stream valleys („Urstromtäler"). These stream valleys carved more and more through the melting fields of glacier remnants and the underlying plains of the ground moraine. This eventually led to the modern shape of the area, which is a landscape carved through a web of river valleys (Slobodda 1977; Succow 1970).
Because of its relative large proportion of semi-natural to near-natural vegetation, the Peene river valley counts to the best preserved German valley fens. Therefore, in 1992 the Peene river valley was declared area of national conservation significance for Germany. The German Ministry of Environment, Nature Conservation and Nuclear Plant Security (BMU), via the Federal Agency for Nature Conservation (BfN), granted funding for the long term protection of the 20,000 ha core zone. Including the co-financing by the federal state of Mecklenburg-Western Pomerania, the surrounding municipalities and the Kurt Lange foundation in total about 28,5 Million Euro were spent. The main goals of this were (Lenschow & Eichstädt 1993):
1. preservation and long-term protection of the natural and unaffected areas,
2. long-term protection of the valuable wet meadows on fen, which were/are conserved by extensive use (grazing and/or cutting),
3. socially and environmentally sound restoration of the poldered peatlands, which were created during the last four decades for industrial-like production of animal food.
During the project implementation, which lasted 17 years, about 9,000 ha of degraded peatlands could be rewetted. 5,400 ha have been purchased for nature protection. In total 50% of the agricultural area was given up for natural succession after re-wetting. After hydraulic restoration another 2,400 ha were converted to low intensity wet meadows and pastures.

Biodiversity of habitats and species improved substantially. Today, nature near and semi-natural biotopes, typical for fen peatlands, dominate.
The nature park Peene valley was founded in 2011 and covers 33,400 ha. In 2017, an alliance of the Greifswald Mire Centre together with regional NGOs has proposed to designate the Peene valley as Ramsar site (decision at the level of the federal state of Mecklenburg-Western Pomerania is still pending).

What is paludiculture?

Paludiculture is the agricultural or silvicultural use of wet and rewetted peatlands. Paludiculture uses spontaneously grown or cultivated biomass from wet peatlands under conditions in which the peat is conserved or even newly formed (Wichtmann & Joosten 2007).
Paludiculture differs fundamentally from drainage-based conventional peatland use, which leads to huge emissions of greenhouse gases and nutrients and eventually destroys its own production base through peat degradation.
Paludiculture allows the re-establishment and maintenance of ecosystem services of wet peatlands such as carbon sequestration and storage, water and nutrient retention, as well as local climate cooling and habitat provision for rare species.
Paludiculture implies an agricultural paradigm shift. Instead of draining them, peatlands are used under peat-conserving permanent wet conditions. Deeply drained and highly degraded peatlands have the greatest need for action from an environmental point of view, and provide the largest land potential. The implementation of paludiculture is the best choice for degraded peatlands.
Paludiculture is a worldwide applicable land management system to continue land use on rewetted degraded peatlands. Various plants can be cultivated profitable under wet conditions.
To safeguard the main goals of paludiculture, peat conservation or even peat formation, only plants can be cultivated which do not require a regular preparation of the soil. Thus annual or short living plants can only be paludi-crop if the plants can be cultivated within a closed layer of permanent crops (e.g. sundew (*Drosera*) within a peatmoos (*Sphagnum*) lawn). Wetlands plants cultivated for their belowground parts (e.g. Water Chestnut, *Eleocharis dulcis*) are no paludiculture plants as well. A classification and assignment of useful wetland plants and potential paludiculture plants is given in the database of potential paludiculture plans (DPPP).
Paludiculture is also a land use alternative for natural peatlands particular for regions where the increasing demand for productive land drives the drainage. Because of their vulnerable ecosystem services, pristine peatlands should best be protected entirely.

If land use on peatlands is unavoidable, paludiculture should always be given preference over drainage-based land use. For more information see: Wichtmann, Schröder & Joosten (2016).
In regions where already most of the peatland area is affected by drainage and utilisation, the land use change towards paludiculture has to consider the existing nature conservation values. Thus the establishment of new redbeds (e.g. *Phragmites australis*) on (wet) meadow sites should be omitted if different goals for nature conservation are set out. These sites should be used as wet meadows to preserve and improve their habitat value. Planting of new wetland crops can be better realised on degraded sites without any value for nature.

Further reading

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Excursion 1

VEGETATION, GREENHOUSE GAS BALANCE AND BIOMASS USE ON REWETTED PEATLANDS NEAR MALCHIN

Wendelin Wichtmann | Christian Schröder | Felix Reichelt | Wulf Hahne

Meeting point | Bus station (parking space for buses at the Karl-Marx-Platz/small roundabout traffic next to the pedestrian underpass)

Schedule

Start	End	Action	Comment
08:15	08:30	register, boarding the bus	hand out excursion guide
8:30	09:00	Bus transfer	explanation of the programme, description of the landscape
9:15	10:15	stop at polder Randow-Rustow	rewetting measures, water buffaloes for land care
10:15	11:00	bus transfer to Demmin, boarding the passenger boat	
11:00	12:30	boat trip Demmin- Aalbude	view interesting peatland sites, lunch, watching beavers
12:30	13:15	watch tower at polder Große Rosin	rewetted polder, new nature after rewetting
13:30	14:00	bus transfer	
14:00	15:00	Neukalener Seewiese	GEST approach for estimating GHG emissions from peatlands, vegetation management
15:00	16:00	Neukalener Seewiese	rare plant species on wet peatlands under management, harvesting wet meadows
16:00	16:30	bus transfer to Malchin	
16:30	17:15	heating plant Malchin	technical specification of the biomass heating plant, biomass-fuel consumption, performance
17:15	18:30	bus transfer to Greifswald	

Route of excursion 1

Excursion sites

The valley of the Peene river is one of the largest fen areas in Germany, consisting of 45,000 ha, and is known as the 'amazon of the north' because of its wild character. From 1992 to 2008 large areas of fens in the Peene valley were rewetted, creating an outstanding nature conservation area.

Polder Randow Rustow: Compensation measures for highway A 20. Development from intensively used grassland after rewetting during > 15 years, water buffaloes grazing wet sites for landcare

Until the late 1990's the polder Randow-Rustow was intensively used as a high-productive grassland polder with dikes and pumping stations in order to regulate water levels for optimal agricultural use. In the context of compensation measures for crossing the Peene valley with the new highway A 20, the restoration of the polder was planned. With respect to the specific demands on the compensation measure, resulting from the implementation of the EU-Directives "Fauna-Flora-Habitat" and "Bird Conservation", a simple flooding of the polder would not achieve a suitable replacement of the affected sites. Thus a controlled rewetting over a period of 15 years was chosen in order to allow a slowly adaptation of the existing, untypical fen vegetation and shifting towards fen specific vegetation. The water table was risen (dikes and pumping station still existent) in three phases until reaching the level of the river Peene. This 310 ha degraded "fen-polder" now has developed into a peat- forming flood-mire since its rewetting in 1999-2000 has started (Theuerkauf et al. 2006). Today, after 17 years, the restoration is on a good way. Especially the floristic and avifaunistic results are very promising. At present we see a nature reserve rich in different structurally rich habitats such as sedge-swamps, flood-meadows, open water, reeds and willow-shrubs. It is already inhabited by otters, beavers, bitterns, white-tailed eagles, ospreys, marsh harriers, black terns, whiskered terns, lapwings, bluethroats, snipes, penduline tits, moor frogs and tree frogs. A part of the edge to the mineral ground is grazed by water buffaloes.

By boat from Demmin to Aalbude

On this section of the river valley we will see numerous rewetted peatland sites, wet meadows and pastures partly managed by nature conservation, other sites forested with black alder. During the boat trip we will have a lunch meal on the boat. Maybe beavers can be observed, many beaver lodges will be passed by.

Große Rosinwiesen

North-west from lake Kummerow a large polder called „Große Rosinwiesen“ has been established in the 1960s by “Komplexmelioration” and used intensively as grassland, with water levels during summer at 80 cm below surface. In 2005-2008 rewetting of 840 ha has been planned and realized by the Landgesellschaft Mecklenburg-Western Pomerania (Association for Rural Development), mainly financed by European funds within the federal programme for peatland protection. Especially during migration periods in autumn and spring, waterfowl, waders and other rare bird species can be observed. From the bus we can see a cormorant colony nesting in black alders which died off after the rewetting of the polder.

Neukalener Seewiesen

As an alternative for drainage based utilization of peatlands, Hans Voigt and Ludwig Bork demonstrate alternative and economically beneficial uses of biomass produced from rewetted peatland in the Peene river valley. Peatland restoration measures affected 400 ha of land that farmer Hans Voigt had used for cattle breeding. The change in water level affected the species composition of the sites, lowered fodder quality and made the vegetation unsuitable for cattle feeding. Therefore, the family pioneered in using sedge and reed biomass for generation district heating.

At the Neukalener Seewiesen the excursion will split into two groups. One group will deal with the assessment of greenhouse gases from peatlands, the other one with plant species biodiversity. After one hour these groups will switch between the two topics.

Greenhouse gas Emission Site Types (GESTs)

Greenhouse gas emissions are corresponding to water table, temperature, plant growth and land use. These parameters may differ from year to year. Previous studies could show that the medium water table is the best proxy for the assessment of GHG emissions from peat soils. The recently updated GEST approach based on more than 490 CO_2- and CH_4-publications on GHG emissions providing data on average water tables and land use. This is an appropriate basis for the assessment of GHG emissions from organic soils. It consists of 30 so called Greenhouse gas Emission Site Types (GESTs).

During the field excursion we will study a former polder and try to assess the GHG emissions via GESTs on ground. The relationship between water tables, land use and vegetation, which are the basis for the classification of GESTs approach development, will be explained.

Based on these parameters we will give an overview on the steps for GEST assessment (mapping of vegetation, water-table classes, GEST correlation, spatial reference). Together at one point we will assess GESTs exemplarily, using site parameters and vegetation data on site. Finally, we will discuss the most important criteria and specifications for conservative GHG assessments through the GEST approach.

Vegetation of rewetted, regularly harvested fen peatlands – homogenous vegetation versus highlights of biodiversity

The history of amelioration and utilisation of the Neukalener Seewiesen polder system will be presented, the current land use practices will be explained and examples for the plant species composition and their dependency on management activities will be discussed. Some rare species (red list Mecklenburg-Western Pomerania) will be observed.

The excursion will visit a very species rich wet meadow-complex in the northern part of the rewetted polder Salem-Neukalen. Besides dominating sedge-meadows also some mosaics of Reed Canary Grass meadows occur, as well as Reed Mannagrass (*Glyceria maxima*) dominated patches. Small areas are covered by Common Sedge or Black Sedge (*Carex nigra*). Red list species like Marsh stitchwort (*Stellaria palustris*), Ragged-Robin (*Lychnis flos-coculi*), Brown Sedges (e. g. *Carex disticha*) as well as Common Meadow-Rue (*Thalictrum flavum*) are remarkable. The area of the wet meadow complexes notably increased after the pumping station was closed down. As, since that time, the groundwater tables are corresponding with the water tables of the Lake Kummerow, from time to time the peatland is fully inundated, depending on the wind and water table conditions of the lake. The southern part of the area is managed by cattle grazing, the northern part is regularly mown. The hay harvested there is used as a fuel in the biomass heating plant in Malchin. To preserve and improve the further development of species rich vegetation it is absolutely necessary to continue the developed land use system.

Selected plant species at Neukalener Wiesen:

Agrostis stolonifera, Alopecurus geniculatus, Cardamine pratensis, Carex acuta, Carex disticha, Carex acutiformis, Carex nigra, Carex riparia, Deschampsia cespitosa, Eleocharis palustris, Filipendula ulmaria, Galium palustre, Glyceria fluitans, Glyceria maxima, Iris pseudacorus, Juncus effuses, Lychnis flos-cuculi, Lysimachia vulgaris, Mentha aquatica, Myosotis scorpioides scorpioides, Phalaris arundinacea, Persicaria amphibia, Plantago major, Poa trivialis, Potentilla anserina, Ranunculus repens, Symphytum officinale, Stellaria palustris, Thalictrum flavum

Biomass heating plant Malchin

The decision to build up a heating plant to use the hay from wet meadows (Neukalener Seewiesen) as a fuel in completion to feed cattle and dairy cows were multifold: as fertilization on the rewetted fen peatlands is not allowed, on the long run the biomass quality was no longer good enough to feed cows. To ensure financial stability for the farmer Hans Voigt and his family, an alternative use for the biomass, now mainly

sedges, reed and reed canary grass, was needed. After several years of planning, and working cooperation with on-going research projects at the University of Greifswald, the thermal utilisation of fen biomass was chosen as a promising alternative.
An optimal scheme for harvesting hay as a fuel on 250- 350 ha could be elaborated, which provides the regular demand of a regional heating plant with biomass. The local energy provider could be convinced to cover the basic load for heat provision of about 500 households, a school and a kindergarten in the city of Malchin by using bioenergy.
With side adapted machinery the 2-4 t of biomass per hectare can be cut, swathed and baled in summer during dry periods. Approximately 6,000 bales, each with a weight up to 250 kilograms, are harvested per year. The heating plant has been constructed by Ludwig Bork to convert this fen biomass to heat. In addition to the reduction of the emissions from the formerly drained peatland, the 1,000 t of harvested fen biomass provide a total energy supply of 4 GWh and replaces 375.000 l of fossil heating oil. Adding value on rewetted peatland the thermal utilisation of the fen-biomass enables farmer Hans Voigt to continue the use of his land, keep his employees and preserve the natural heritage. The local production of sustainable biofuels increases regional collaboration and added value. However, to increase acceptance of peatland rewetting and restoration for climate and regional development, it is vital to create local networks between land users, administration, district heating stations and energy user. Thanks to the initiative of Hans Voigt and Ludwig Bork the benefits of the alternative land use of peatlands can now be presented to other communities and farmers to go in the same direction.

Peatland rewetting is the best option for climate and nature protection but leads to a loss of land that can be used for agriculture and therefore reduce the income of the local farmers. There is another choice than peatland rewetting and free succession of vegetation for the farmers: Paludiculture. This is an option for farmers, to keep their rewetted peatlands under productive use. Hans Voigt and Ludwig Bork are demonstrating alternative and economically beneficial uses of biomass produced from rewetted peatland in the Peene valley.

Links

http://www.niedermoor-nutzen.de/
http://www.paludiculture.uni-greifswald.de/en/index.php
http://www.succow-stiftung.de/wetland-energy-sustainable-use-of-wet-peatlands-in-belarus.html

Excursion 2

LAND USE HISTORY, MOWING MACHINERY AND BIOMASS USE FOR BUILDING MATERIAL AT PEENE RIVER MOUTH

Tobias Dahms | Franziska Tanneberger

Meeting point | Bus station (parking space for buses at the Karl-Marx-Platz/small roundabout traffic next to the pedestrian underpass)

Schedule

Start	End	Action
08:15	08:30	register, boarding the bus
08:30	09:30	Travel Greifswald - Gnevezin
09:30	12:15	Gnevezin (reed harvesting machine “Seiga”), view on reed cutting areas at “Ferne Wiesen”), Anklamer Fähre (tracked harvesting machine), view on rewetted and flooded areas near Kamp
12:15	13:00	Lunch break at Kamp harbour
13:00	14:00	Walk across Kamp village, thatched roofs, cattail-insulated house
14:00	15:00	Ferry travel from Kamp to Karnin, bus travel to Zecherin
15:00	15:30	Zecherin (reed weaving machine)
15:30	17:00	Bus transfer to Greifswald

Route of excursion 2

Landscape

In the Peene river valley typical valley mires are widespread. They consist of spring fens at the margin, a river with adjoining flood mire at the base and extensive percolation mires in between. With an area of 17,810 ha the Peene Valley is the largest fen complex in western Central Europe. During the excursion we will visit the mouth of Peene river, located east of Anklam. The peatland is largely of flood mire origin and predominantly formed of reed peat.

About 30 other Annex I species use the area as a resting or feeding place, e.g. *Gavia arctica, Cygnus cygnus, Aythya nyroca, Mergus albellus, Circus pygargus, Aquila pomarina, Crex crex, Pluvialis apricaria, Asio flammeus, Bubo bubo, Acrocephalus paludicola. Castor fiber* and *Lutra lutra* are common in stable populations. Also *Bombina bombina* and *Triturus cristatus* occur. Among the invertebrates the stable populations of the Annex II species *Carabus menetriesi* and *Lycaena dispar* are especially important.

Biodiversity values of Peene Valley

At present, the lower Peene valley still includes a wide variety of wetland types and is a refuge for several rare plant communities and plant and animal species. Remains of wetland types originally widespread in northeastern Germany such as alkaline fens, transition mires and calcareous fens with *Cladium mariscus* and *Carex davalliana* still exist in the lower Peene valley. Here, rare plant species grow, such as *Betula humilis, Primula farinosa, Carex buxbaumii, Carex hostiana, Calamagrostis stricta, Dianthus superbus, Pedicularius sceptrum-carolinum, Saxifraga hirculus, Liparis loeselii, Epipactis palustris* and *Euphorbia palustris*.
The Peene valley is important for a number of rare breeding bird species: *Botaurus stellaris, Milvus milvus, Haliaeetus albicilla, Circus aeruginosus,*

Porzana pozana, Grus grus, Sterna hirundo, Chlidonias niger, Chlidonias hybridus, Alcedo atthis, Luscinia svecica, Dryocopus martius, Sylvia nisoria and *Lanius excubitor*.

Land use history

Traditionally, the undrained or slightly drained peatlands at Peene river mouth were used for grazing, hay-making and locally also for peat cutting. Most parts of the mire have been under continuous use since medieval times. Its narrowness made it easily accessible and enabled an early use. During 1300-1800, the mire was part of the common land (German: Allmende) and land use was hardly differentiated, a general characteristic of agriculture at that time. The intensity of use varied with the ups and downs of society and with population density. Meadows occupied 23 % of the mire. About one half, located closer to the villages, was mown annually; the rest less frequently. The largest part of the mire was used as pasture, mainly for cattle – 22 % were grazed regularly and 55 % only sporadically. Both meadows and pastures were characterised by superficial drainage.

The medieval tradition of common lands ceased and the now private land was parcelled and more intensively used. Levelling and improved drainage allowed the exclusive use as meadows. Until the mid 19th century the spacious and still wet common pastures were transformed into small patches of better drained meadows interrupted by peat pits – and the traditional paludiculture use ceased. This new, more strongly drained use dominated until 1920. In the 1920s, the state initiated and funded the formation of cooperatives responsible for largescale drainage of the mire. Until World War II large areas were poldered and used as high-intensity grassland after ploughing. After 1960, agricultural use on half of the peatland was further intensified by the establishment of high intensity grassland monocultures (complex melioration, German: 'Komplexmelioration'). The formation of cooperative farms eliminated the fine-scale landscape pattern of the fen meadows. Areas that were not used, mainly the former peat pits, were invaded by shrubs and trees. Eventually one third of the peatland was forested and 17 % covered by shrubs. After 1995, the polder system was abandoned and large parts of the peatland were given back to nature. This initiated the transition towards a landscape dominated by wetlands and carrs.

Current land use

Today, while part of the peatlands is still used as high intensity grassland, the rewetted parts are either abandoned, used for conservation mowing or for reed cutting. Conservation mowing is implemented on c. 150 ha wet peatland at Peene river mouth by a local nature conservation NGO (Förderverein Naturschutz im Peenetal e.V.) in cooperation with local farmers and supported by the foundation OSTSEESTIFTUNG. Reed cutting for thatch is currently practiced on c. 80 ha at Peene river mouth. In the region of Western Pomerania, in total 10 companies are active in reed cutting on a total area of c. 550 ha. Both "Seiga" type and tracked machinery are used by the reed cutters. Reed cutting is in Germany not eligible for agricultural subsidies. Reed cutters are interested in enlarging the reed cutting area.

Recently, new and innovative ways of using plants from wet peatlands as building material emerged. In Kamp, a tourist house (see below) was insulated with reed and cattail.

Tourist house in Kamp/Wetland Products Foundation

In 2014 the Dutchman Aldert van Weeren bought a 19th century house in Kamp, which will be visited during the excursion. His intention was to use it as guest house for nature tourists that are attracted by the beautiful landscape of Peene river mouth. Using local building material from rewetted peatlands was an obvious (but still rarely practiced) approach.

In cooperation with the University of Greifswald, a local farmer, local reed cutters and two factories in Prenzlau and Waren teamed up to produce 75 m³ blow-in insulation made from cattail and fire proof construction panels made from waste incurring during the production of thatching reed. These building materials were used for the renovation of the guest house. Cattail biomass is, due to its sponge-like tissue including a large amount of air-filled cells (aerenchyma), an outstanding natural insulation material.

Inspired by his findings, Aldert van Weeren founded the Wetland Products Foundation. The foundation's objective is to develop and promote building materials from wetland plants in Germany and The Netherlands.

Nature conservation

The Peene is the best-preserved valley mire in Germany and a refuge for rare plant and animal species (see introduction above). The Peene valley is a Special Protected Area (SPA, since 1990, 20,000 ha). The nature reserve 'Unteres Peenetal (Peenetalmoor)' is an important bird area (IBA, since 1988). Since 1992 the large-scale conservation and restoration project 'Peenetal/Peene-Haff-Moor' has been implemented to create a protection area of 45,000 ha covering the whole valley mire and including a core area of 20,000 ha of strict nature reserves.

Research

The effects of summer conservation mowing at Peene river mouth are studied since 2006 by a local nature conservation NGO (Förderverein Naturschutz im Peenetal e.V.). Summer mowing can convert high and dense reed beds in the flood mire part rather rapidly into moderately high, sparse sedge vegetation rich in herbs. Bird species such as lapwing and redshank, and plant species such as *Liparis loeselii* seem to benefit.

With the EU project REPEAT partners from Antwerp, Warsaw and Greifswald universities study the effect of machine mowing on peat formation in fens in 2017/2018. Vegetation composition, soil and root properties as well as decomposition rates are compared at paired mown and unmown plots in Recknitz and Peene valleys. Mowing includes light tractors and tracked machinery. Here and at additional pairs in the Netherlands and Poland, also below-ground production and decomposition of fine roots is studied. Results will become available in 2018.

Within the EU project CINDERELLA partners from Aarhus, Halmstad, Nijmegen and Greifswald use a cattail site near Kamp as one of their field sites. The project applies a transdisciplinary research approach to study crop production related to soil, climate conditions and genetic characteristics, as well as nutrient removal and supply, biogeochemistry – of soil, water and carbon dynamics. Results show that the production of cattail on rewetted peatlands can, at optimal water table, combine high biomass productivity, high nutrient uptake and low emission of greenhouse gases.
The project also includes sustainability as well as micro- and macro-economic assessments. In Kamp harvesting trials, biomass processing and use as building materials is monitored and integrated into a broader economic analysis and a life cycle assessment. Using a balloon-tyred "Seiga" machine, c. 3 ha of cattail were harvested as bundles in winter 2016/17, yielding 7.5 t DM/ha.

Further reading

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Links

Paludiculture | www.paludiculture.com
Förderverein „Naturschutz im Peenetal" e.V. | www.naturschutz-peenetal.de
Zweckverband Peenetal-Landschaft | www.peenetal-landschaft.de
Stichting Wetland Products | www.wetlandproducts.com
REPEAT project | www.repeat.paludiculture.com
CINDERELLA project | www.cinderella.paludiculture.com

Excursion 3

PEATLAND REWETTING, LAND USE AND BIRDS IN LOWER PEENE RIVER VALLEY

Nina Seifert | Franziska Tanneberger | Cosima Tegetmeyer

Meeting point | Bus station (parking space for buses at the Karl-Marx-Platz/small roundabout traffic next to the pedestrian underpass)

Schedule

Start	End	Action	Comment
08:15	08:30	register, boarding the bus	hand out excursion guide
08:30	09:30	Bus transfer	
09:30	10:30	Naturparkhaus Stolpe	Visit at the information and administration centre of the Peene river valley nature park (Naturpark Peenetal)
10:30	11:30	Bus transfer	
11:00	13:00	Anklamer Stadtbruch	
13:00	13:30	Bus transfer	
13:30	14:30	Lunch in Libnow	
15:00	16:00	Polder Immenstädt	Restoration of a former grassland polder as a compensation measure
16:00	17:00	Bus transfer to Greifswald	

Route of excursion 3

Introduction

The Amazon of the North - a remarkable commercial slogan quite often heard in recent years when talking about the Peene valley. Of course, the comparison is a slight exaggeration considering the length of the two rivers (85 km vs. 6,387 km), the size of the catchment area (5,512 km^2 vs. > 7 mio km^2) and the discharge (24.5 m^3/s vs. 190.000 m^3/s). Most importantly and in contrast to the Amazon, the Peene has been part of a cultural landscape for centuries.

Yet on a Central European scale, the Peene valley is a wild, exciting and „natural“ landscape. The Peene is the best-preserved valley mire in Germany and a refuge for rare plant and animal species. A total of 20.000 ha of the Peene valley is included in the German list of valuable natural areas and landscapes of national importance. It is a special protected area (SPA, DE 2049-302 „Peeneunterlauf, Peenestrom, Achterwasser und Kleines Haff & DE 2045-302 „Peenetal mit Zuflüssen, Kleingewässerlandschaft am Kummerower See“) and a SPA according to the European Birds Directive (SPA DE 2147-401 „Peenetallandschaft“). Furthermore, almost the entire course of the river and its adjacent flooding and rewetted areas are recently designated as protected areas („Peenetal von Salem bis Jarmen“, „Schwingetal und Peenewiesen bei Trantow“, „Peenetal von Jarmen bis Anklam“ and „Unteres Peenetal (Peenetalmoor)“).

Natural vegetation

In their natural state, Central European river valley mires were largely open as the dominant percolation mires did not offer enough support for large trees to grow. Detailed macro- and microfossil analyses carried out at the University of Greifswald enabled the reconstruction of past vegetation patterns and their dynamics. The percolation mires were over vast stretches dominated by low to medium high sedges without clear zonation. Dominant sedge species included *Carex rostrata, C. diandra, C. limosa, C. chordorrhiza* and *C. dioica*. Further characteristic herbs were *Menyanthes trifolia, Cardamine dentata, Galium uliginosum, G. palustre,*

Thelypteris palustris, Cicuta virosa and *Peucedanum palustre*. The moss layer was dominated by brown moss species like *Drepanocladus* ssp., *Meesia triquetra, Calliergon giganteum* and *Homalothecium nitens*. In small water filled hollows furthermore *Utricularia intermedia* and *Characea* species occurred. On hummocks, occassionally shrubs of *Betula humilis, B. pubescens* and *Salix repens* ssp. *repens* were present. The reconstructed vegetation is very similar to the present day vegetation of near natural sedge fens in Eastern Europe, e.g. Biebrza, Narew, Bug and Pripjet.
Nowadays, only remnants of the natural fen vegetation are found in the Peene valley.

History of land use

Valley mires are a common landscape feature in northern Central Europe and have been heavily drained and used for centuries. The Peene valley is the least affected, most natural river valley mire in Mecklenburg-Western Pomerania; a notion that until recently has concealed that most parts of the mire have been under continuous use since medieval times. Its narrowness med it easily accessible and enabled an early use. Three concise major phases of land use can be distinguished.

I. Medieval- early modern period meadow and pasture landscape (1300 - 1800)
The first maps which were produced in the framework of the Swedish fiscal registry survey (1692 - 1709) documented that meadows occupied around 23% of the mire. About one half, located closer to the villages, was mown annually, the rest less frequently. The largest part of the mire was used as pasture, mainly for cattle - 22% were grazed regularly and 55% only sporadically. On these pastures superficial drainage and the formation of hummocks by trampling cattle allowed scattered establishment of shrubs and trees. The pastures thus reminded rather of open woods and shrubland. However, in general, the share of shrubs and woods did not yet altered the open character of the prevailing landscapes typical for pristine river valleys.
Land use intensity varied with the ups and downs of society and with population density. This is e.g. reflected by the widespread occurrence of denser shrubland (25%) and woods (12%) revealed by the Swedish fiscal maps, which indicate a reduced intensity of land use and abandonment in the 17th century, when Vorpommern lost about 40% of its population due to wars, epidemics and migration.

II. Landscape of peat cutting and meadows (1850 - 1920)
With the beginning of the 19th century, land ownership was reformed and the importance of peat cutting increased. Peat cutting had been performed on a small scale since medieval times. Since about 1750, however, the Prussian government propagated the use of peat as fuel to reduce the consumption of wood. Since 1800 peat cutting accompanied by intensive drainage became widespread land use in the mire. The medieval tradition of common lands ceased and the now private land was parcelled and more intensively used. Levelling and improved drainage allowed the exclusive use as meadows. Until the mid 19th century the spacious and still wet common pastures were transformed into small patches of better drained meadows interrupted by peat pits.

III. The beginning of large scale drainage (1920 - 1960) and a landscape of polders and swamps

In the 1920s, the state initiated and funded the formation of cooperatives responsible for large-scale drainage of the mire. Until World War II large areas were poldered and used as high-intensity grassland after ploughing. During the war these constructions were neglected and partly collapsed.

From 1960 to 1995, two very different developments took place. Agricultural use on half of the peatland was further intensified by the establishment of polders with high intensity grassland monocultures (complex melioration). The formation of cooperative farms eliminated the small-scale landscape pattern of the fen meadows. Areas that were not used, mainly former peat pits, were invaded by shrubs and trees. Eventually one third of the peatland was forested and 17% was covered by shrubs. From 1995 on, the polder system was abandoned and large parts of the peatland were given back to nature. This initiated the transition towards a landscape dominated by wetlands and carrs.

Anklamer Stadtbruch

The extensive Anklamer Stadtbruch comprises 1,461 ha which were rewetted in 1995 after an unintentional levee breach as a consequence of a storm surge. Since then, large parts of the forest died off and disappeared or were replaced by tree species such as Ash, Alder and Birch. Not only due to the occurrence of a rather extensive raised bog in the center, the site is protected area since 1934.

Nowadays, the Anklamer Stadtbruch is well known for its rich lepidofauna with populations of rare diurnal butterfly species such as e.g. *Chariaspilates formosaria*. More than 100 breeding bird species are found and the site is famous for the “colonial” breeding of the majestic White-tailed eagle (*Haliaetus albicilla*).

Polder Immenstädt / Johannishofer Wiesen

The former polder embraces more than 800 ha and is part of the project “Restoration of Polder Pinnow and Immenstädt”, a compensation measure in the framework of the construction of the Nord Stream gas pipeline.

Originally, the site was a percolation mire, but after extensive drainage following World War II the polder was used as a high-intensity-grassland with substantial degradation of the upper peat layer. In 1999 the site was rewetted in the framework of the large-scale restoration project “Peenetal/Peene-Haff-Moor” and since 2015, further restoration measures are being implemented by the Flächenagentur M-V GmbH. Nowadays, the site is an important breeding and staging site for water birds. E.g. during migration, rare wader species can be regularly observed.

Restoration

The large-scale restoration and rewetting of the river valley mire Peene started soon after the political transition in Eastern Germany, the „Wende“ in 1990. Already in 1992, the Peene-Valley was acknowledged as the best preserved and largest river

valley mire in Germany and thus an „Area of National Importance for Nature Conservation“. In the same year, the restoration project „Peenetal/Peene-Haff-Moor“ was being implemented to create a conservation area of 45,000 ha covering the entire valley mire, including a core area of 20,000 ha of strict nature reserves.
The goals of the project were:
- The preservation and to some extent restoration of the river valley mire, meaning a growing peat layer due to the amelioration of the hydrological regime as well as deconstruction of polders.
- The protection and re-establishment of a typical biodiversity depending on an extensive land use regime.
- The protection of the entire bottomland as a crucial refugium for breeding birds as well as an important staging site during bird migration.
In the course of the implementation of the restoration project, the administration union „Peene valley landscape“ (Zweckverband Peenetallandschaft) was established, being an institution representing the adjacent administrative districts (Mecklenburgische Seenplatte and Vorpommern-Greifswald), and towns (Demmin, Loitz, Jarmen, Gützkow, Anklam) in the Peene Valley as well as the „Association for the Protection of the Peene valley“.

The Aquatic Warbler

The Aquatic Warbler *Acrocephalus paludicola* is a typical fen breeding bird. Formerly it occurred from the North Sea coast to Siberia. It was a common bird in Vorpommern before the First World War as historical sources prove. With the destruction of its habitats by deep drainage and progressive intensification the population declined strongly. Today the species is disappeared from many countries and the world population consists of about 17,000 singing males. The Aquatic Warbler is therefore the rarest among European migratory songbirds and the only globally endangered songbird species on the European mainland. About 90 % of the world’s population breed today in the border triangle between Poland-Belarus-Ukraine. There is a small occurrence on the Baltic coast of Lithuania, where in the recent years specific management measures lead to a slightly increase of the local population (www.meldine.lt). On the German-Polish border an isolated population occurs (the so - called „Pomeranian population“), which is actually threatened with extinction. From 2005-2011, the Nature Conservation Association “Förderverein Naturschutz im Peenetal e.V” was the German project partner of an EU-funded LIFE project to protect the Aquatic Warbler in Poland and Germany (www.wodniczka.pl). Around the Peene estuary large fen meadows were converted into suitable habitats for the species by reintroduction of mowing. There was hope that these meadows would be resettled by the only 30 km airline neighboured next Polish occurrence. The project was carried out in close cooperation with the “Zweckverband Peenetal-Landschaft” and the Nature conservation authorities. By the mowing in the Peene estuary many positive effects for the flora and other grassland birds such as Lapwings and Redshanks could be reached. Unfortunately, the Aquatic Warbler has not yet been introduced despite suitable habitats returned in the Peene valley.

Probably there are not enough birds anymore to spontaneously re-colonize these areas. The „Pomeranian population“ is today with about 10 singing males reduced in numbers as never before. The “Förderverein Naturschutz im Peenetal” is therefore involved in concrete protective activities in the last remaining major Polish breeding area.

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Excursion 4

PEATLAND RESEARCH ON MOWN AND GRAZED REWETTED PEATLAND IN RECKNITZ AND TREBEL RIVER VALLEYS AND ON DARSS PENINSULA

Anke Nordt | Andreas Haberl

Meeting point | Bus station (parking space for buses at the Karl-Marx-Platz/small roundabout traffic next to the pedestrian underpass)

Schedule

Start	End	Action	Comment
08:15	08:30	Meeting for excursion at Greifswald central bus station	Final registration on board
08:30	09:30	Transfer from Greifswald to Recknitz river valley near Bad Sülze	Introduction to the program of the day, introduction of participants, some background information on peatlands in Mecklenburg-Western Pomerania
09:30	10:30	Stop at Bad Sülze Polder II	Rewetted Polder under management within the „Ökokonto“ programme
10:30	11:30	Stop at Bad Sülze Polder III	Rewetted Polder GHG measurement site of research project “WETSCAPES”
11:30	12:00	Transfer to lower Recknitz river valley near Freudenberg	Distribution of lunch packages, backgroundinformation on biodiversity project HOTSPOT 29-“Schatz an der Küste“ implemented in Western Pomerania. If needed stop at public toilet along the way
12:30	13:45	Recknitz river valley near Freudenberg	Break for lunch and coffee parallel introduction to HOTSPOT29 activities here. Demonstration of energy biomass harvest from wet peatland site
13:45	14:30	Transfer to coastal lagoons and peatlands on the Darß	Background information on coastal peatlands and Salt meadow restoration and management. Traditional reed bed utilisation for roof thatch in the region
14:30	17:00	Agricultural enterprise “Gut Darß”	Management of wet peatland meadows with Waterbuffaloes. Marketing of waterbuffaloe products visit of Farm shop. Visit of managed sites with waterbuffaloes
17:30	19:00	Returntravel to Greifswald	If participants need to leave at Stralsund train station it is possible to stop along the way

Route of excursion 4

Landscape

The Recknitz valley is part of the river valley peatland sytem in Mecklenburg-Western Pomerania in North-East Germany. It rises in a plateau of undulating ground moraines of the last glacial period (~10,000 years BP). In this plateau river valleys where ice-scored and extend SW-NW in direction of the Glacier progression and flows into the Saaler Lagoon near Ribnitz-Damgarten. The river Recknitz enters at Bad Sülze the Pommeranian plain and turns ~90 degrees to the North forming a bifurcated watershed with the River Trebel. In this watershed, the Grenztalmoor is situated. Together with the rivers Trebel and Tollense the Recknitz delineates the Western margin of the Pomeranian plain in NW-SE direction as meltwater valleys perpendicular to the retreating glacier front of the last glacial period. During the Littorina Transgression of the Baltic Sea ~7,000 BP these valleys where flooded with brackish water and water rise mires formed and accumulated large *Phragmites*-radicell peat deposits. Later extend percolation mires in the up to three-kilometer wide valley formed sedge peat deposits on top of these. Total peat depth in the Recknitz valley is up to >8 m.

The overall length of the river today is about 88.9 km with a small water level gradient of about 0.3 m between Bad Sülze and Ribnitz-Damgarten. High water levels at Saaler Lagoon may lead to backwater up to Bad Sülze, about 30 km inland. The first river regulations took place in early 20th century to increase water runoff. More followed until the 1960s, which reduced river course from 122 km to 69 km. Hydrological regulations comprise nine weir systems, two pumping stations, and installation of dikes to intensify grassland utilization.

With ongoing drainage, problems of topsoil desiccation and degradation of top peat layers arose. Consequent loss of water absorption capacity and loss of vertical capillary transport capacity of the peat resulted in lower productivity and reduction in flora and fauna species. Since 1990, a landscape protection area comprises about 5.450 ha of river, peatlands and hillside along its way.

It includes three nature conservation areas and is registered as SPA and as FFH area. Main protection goal is to maintain the large-scale spacious unspoilt landscape integrating environmentally sustainable land use. About 200 ha of reed beds in the river valley and on Darß-Pensinsula are harvested for thatching houses. Agricultural use comprises mainly grassland. Since 2000 part of the river valley peatlands were rewetted and stream course restored to its original riverbed under different funding schemes.

Adjacent to the North and North East to the Pomeranian plain is the coastal area of the Baltic Sea characterized by a graded shoreline with sand spits and lagoons.

The Fischland-Darß-Zingst-Peninsula is a typical formation of counterbalancing coast dynamics. Coast near abrasive sea currents take material (sand and clay) on westerly exposed shorelines and sediment it easterly at current calm sites forming sand spits. In that way a set of lagoons was separated from the Baltic Sea on a length of ~50 km. The regional name of such a lagoon is "Bodden". Due to the brackish and shallow water regime in the lagoons they are prone to eutrophication caused by nutrient inflow with the surface runoff from intensive agriculture areas in the catchment of the tributary rivers. In consequence, reed grows prolifically and nature conservation measures comprise mowing and grazing to fight back reed encroachment. Traditionally reed is harvested in the area and used as roof thatch. Nowadays in the area the largest national park of Mecklenburg-Western Pomerania the "Nationalpark Vorpommersche Boddenlandschaft" is situated with a size of in total 805 km^2 it ranks third amongst all National parks in Germany.

Traditional roof thatching with common reed (*Phragmites australis*)

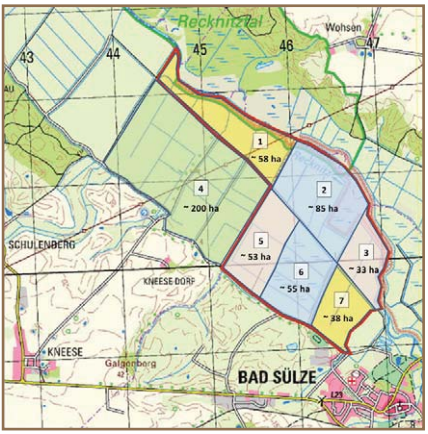
Common reed (*Phragmites australis*) is a globally distributed emergent wetland plant. Everywhere cultures that developed in or next to reed covered wetlands invented manifold application possibilities for reed as construction material. Whole buildings, garments, mats, boats, were and are made from reed. Especially in Europe still wide spread are reed-thatched roofs. Many of the traditional fishing villages in the Fischland-Darß-Zingst area are still characterised by the typical architecture with reed-thatched roofs. Nowadays the touristic region is keen to maintain the traditional scenic appearance of the fisher villages. Traditional craftsmanship for the harvest of reed and the construction of thatch roofs is still present in enterprises and workshops in the region and finds also application in contemporary modern architecture. Local demand for thatch reed cannot be satisfied by local reed resources only. Land degradation and nature conservation restrictions limit the availability of suitable reed beds for the harvest of thatch reed and therefore imports from Eastern Europe and China are necessary (Wichmann & Köbbing 2015).

Paludiculture

Eco-Account Polder Bad Sülze 3

After rewetting of 326 ha in 2015, a management plan defined 5 sub areas, each between 33 ha and 58 ha, to be mown once a year at different times between June and

August, and to remove the biomass. Mowing has to be done with a cutter bar mowing unit. Afterwards grazing with 1 GV/ha is possible until 31st October. Rewetting was expected to raise water level at the parts further away from the river to about 30 cm beneath surface, while the sites close to the river (about 150 ha) were expected to get water table at surface level. Until now water levels remain lower than expected. In 2016 partners from GMC, local farmer and local authorities joint up to develop a local community heating concept in order to utilise the wet meadow material for combustion and district heating. Surrounding settlements and towns were evaluated for heating demand, suitable places to set up a heating plant, potential customer interest, necessary investments, potential funding as well as feasible investor and operator.



Management plan of the Eco Account Polder Bad Sülze 3

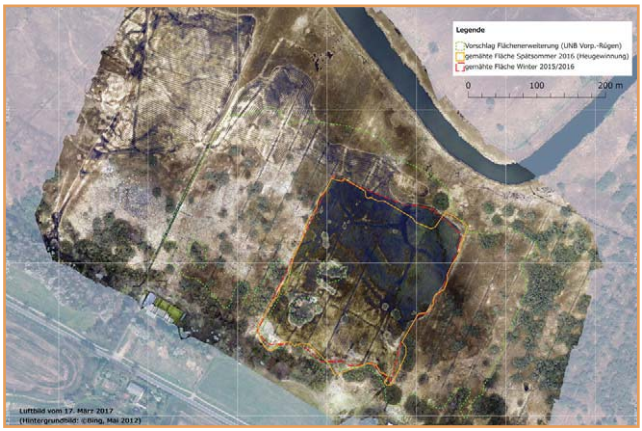
Hotspot 29 „Schatz an der Küste“

It is a joint project for biodiversity protection in the BfN (German federal agency for nature protection) funded Programme “Hotspots of biological diversity in Germany”. The Hotspot 29 project region is one of 30 accredited Biodiversity Hotspots in Germany (BfN 2011) and comprises 1,211.79 km² in the Western Pomeranian lagoon landscape between the Rostocker Heide and the western part of the Island Rugia. The nine project partners in Hotspot 29 deal with diverse issues of biodiversity protection in the project area addressed by:

- ecosystem restoration in the coastal floodplain,
- development of sustainable land use,
- environmental education, and
- participatory measures.

The Succow Foundation processes a work package dealing with the development of adapted technology and management of wet (rewetted) peatlands. In this work package, two model sites in the project region were selected for repeated sustainable utilisation of aboveground biomass (reeds).

One site is located in the lower Recknitz valley near Freudenberg. The first biomass harvest via the project was realised in 2015 by the landscape maintenance company Meyer Luhdorf with tracked special equipment based on a modified snow cat. In order to reduce management costs and to develop an approach that is feasible and attractive for agricultural farms, since 2016 the Succow Foundation cooperates with the agricultural enterprise LWB H. Voigt from Neukalen and an engineer to develop adapted accessory equipment compatible to already adapted trucks (light weighted, and large contact area by huge low pressure wheels) of the enterprise.



Hotspot 29 Model site for paludiculture management in the lower Recknitz valley near Freudenberg. Different harvesting seasons, Winter 2015/2016 (yellow), Summer 2016 (red), extension possibilities for 2017-2019 (green) annually then ~8 ha should be managed.

It was decided to concentrate on the approach of LWB H. Voigt for harvesting energy grass biomass in late summer from wet and rewetted peatland sites for the Agrotherm heating facility in Malchin (see also excursion 1). Another task is to improve the baling unit and the logistics for the clearing of the harvested sites from the baled biomass. A light weighted baler was modified by enlargement of the contact area and ground pressure. For minimising site crossings during the clearing of bales a management practice from dry and mineral soils with a loading-trailer equipped with a deck crane was transferred to be used on wet and organic soils. The trailer was dimensioned for loading 25 bales and equipped with a tandem axis and large low pressure wheels.

“Gut Darß”: Landscape preservation, site management with water buffaloes

The Gut Darß is a certified organic farm situated in the village Born in the Eastern part of the Darß peninsula. The main branch of the enterprise is suckler cow husbandry with in total 4,700 cattle. Additionally it breeds sheep, boers goats, and

water buffaloes. “Gut Darß” produces and markets organic food products. In total “Gut Darß” manages 4,500 ha of pastureland for grazing and for making grass silage (18-20,000 t annually). From the National park “Vorpommersche Boddenlandschaft” it leases 2,000 ha and manages them for landscape maintenance purposes with low intensity grazing by cattle and on 300 ha peatland by grazing with water buffaloes. Beside managing reed encroachment of peatland areas with special floating harvestors especially site management with water buffaloes turned out to be very effective.

Suppressing reed encroachment by site management with water buffaloes

The coastal marshes of the southern Baltic region are typically influenced by brackish water from periodical flooding of the Baltic Sea. Brackish reed beds constitute the natural climax vegetation in these coastal marshes, but grazing by domestic animals has transformed this natural vegetation into an anthropo-zoogenic salt marsh. Grazing has kept the habitat open and created a mosaic of tidal creeks, seasonal pools, brackish pioneer vegetation, salt marshes and reed beds. The spatial variety in diverse habitats encountered in these salt marshes likely supports a more species rich plant and animal community than the apparently monotonous brackish water reed beds. Regular grazing has created a typical salt marsh with many rare species on Schmidt-Bülten, a 28 ha large island in the West Pomeranian lagoon (Saaler Bodden). Abandonment or reduced grazing pressure would cause the vegetation -with its high conservational value - to be lost to succession towards reed beds. In recent years, management of the island focused on grazing by suckler cows with low livestock density (0.6 livestock units per hectare, LU ha^{-1}). However, this low livestock density proved to be insufficient in conserving the salt marsh. Instead, reed beds developed in the wetter areas (soil moisture class 5+) and regular grazing remained restricted to the drier parts of the island (soil moisture class 3+). Parts of the dry area were even overgrazed, resulting in decreased species richness. Since June 2010, water buffaloes have been used for grazing on the island in order to restore the typical salt marsh vegetation and to suppress the encroaching reed beds. A livestock density of 1.0–1.3 LU ha^{-1} and 123–148 grazing days per season proved sufficient to reduce the area of reed beds by 30%. Like the suckler cows, the water buffaloes preferred the drier parts of the island with its high-quality fodder at the beginning of the grazing season. Nonetheless, the animals did disturb the reed beds already early in the season by regular trampling and some grazing on young shoots. As the amount of available fodder dwindles during the course of the grazing season, the buffaloes more regularly feed on the young reed culms, allowing understory plants to benefit (mainly *Agrostis stolonifera* ssp. *maritima* and *Juncus gerardii*). Meanwhile, the suppression of reed has led to an increase in the grazing area (which, in 2012, required a slight increase in the livestock density) in order to keep grazing pressure at the required level (Horn et al. 2016).

“Gut Darß” started with water buffalo breeding with a herd of ~20 water buffaloes in 2007 since then the herd grew rapidly. Today “Gut Darß” has 227 water buffaloes

and therewith reached the capacities of the enterprise and considers to sell in future breeder animals as well. In the marketing branch of the enterprise the water buffaloe meat sells like hot cakes. Local restaurant's, not only during the tourist season, make good deals with the exotic and locally produced organic water buffalo products like with the top seller "Büffel-Burger".

Nature conservation

Along the excursion we will see and visit a range of nature conservation areas at Recknitz valley and the national park "Vorpommersche Boddenlandschaft". Besides rewetting through different rewetting schemes since the late 1990s (EU Life, Moorschutzprogramm MV, "Eco–account") recent funding within the Bundesprogramm Biologische Vielfalt (federal programme for biodiversity, 2014-2020) also includes environmental education, F&E of adapted logistical machinery for wet peatland use and its influence on soil.

EU-Life project restoration of Recknitz river valley peatland (1999-2001)

A conjoint nature conservation project has been implemented within a consortium of different nature conservation and water management agencies under the lead of the State Agency for Environment, Nature conservation and Geology M-V and the Agency for Environment and Nature conservation Stralsund. By implementation of consequent peatland conservation measures the preservation and improvement of threatened wetland animal and plant species in particular the populations of priority bird species was envisaged. The EU funded the implementation of restoration measures with 2.9 mill. DM, the federal state Mecklenburg-Western Pomerania added 1.9 mill. DM of own funds to that (in total ~2,4 mill. Euro). The project area comprises in total 550 ha of the Recknitz river valley from the weir Bad Sülze down to the weir Dudendorf and is part of the EU SPA „Mecklenburger Schweiz, Recknitz und Trebeltal" and of the FFH-area „Recknitztal und mittleres Trebeltal".
Restoration measures comprised:

- reactivation of the natural water course along 9.4 km
- modification of the drainage system
- closing of ditches with sheet pilings
- construction of dams
- artificial river bed elevation
- acquisition of 182 ha land by the federal state M-V for implementation of restoration constructions
- compensation payments to farmers

Research

HOTSPOT 29 „Schatz an der Küste" (2014-2020):
Research in the Hotspot 29 project relevant for Paludiculture comprises a market and area potential analysis for paludiculture in the Hotspot 29 region and a synopsis on available technology for grass biomass harvest on wet, soft, and organic soils.

The first concluded that currently the market would not be ready for innovative Paludiculture products and a simultaneous development of supply and demand is nearly impossible under the current framework conditions. The technology report concluded good potential for upscaling tracked vehicles to an agri-industrial level that could compete in performance with comparable harvesting chains. But investment costs of 600-900,000 € are neither profitable under the currently given scenario for the potential area for paludiculture. Nor are such large scale approaches compatible to sustainable land utilisation approaches and nature conservation targets.
On the model sites for paludiculture management every second year a monitoring of the effects of the site management on soil physical parameters and vegetation development is carried out. Initial monitoring was done in 2015 yielding good results for the management with the tracked vehicle of the landcare company Meyer Luhdorf. In 2017 the monitoring is repeated for the first time.

REPEAT (2017-2020):
REPEAT is a joint project of the universities of Warsaw, Greifswald, Antwerp, the Norwegian Institute of Bioeconomy Research and the Danube Delta National Institute for Research and Development in Romania as well as Wetlands International. REPEAT aims to clarify the mechanisms of peat formation in fens by linking biogeochemical processes to soil community structure and biodiversity, as well as to plant belowground traits. The central research question is: What are the differences in below-ground production and decomposition, and eventually peat formation, between near-natural, drained and rewetted percolation fens along a climate gradient? In addition, we study the effect of trophy in near-natural fens in Eastern Poland and Romania, and assess the influence of machine mowing in near-natural and rewetted sites. The interdisciplinary project investigates both the least disturbed and the most disturbed percolation fens of Europe with a broad array of methods and assesses the restorability of the latter ones. To compare undrained, drained and rewetted fens, it analyses ecosystem processes in-situ in four countries, supplemented by ex-situ mesocosm and laboratory experiments. The project also prepares recommendations regarding ecosystem services and resilience in fen rewetting. A particular focus is on restoration and paludiculture (harvest and use of biomass in wet peatlands). Stakeholders in participating countries are addressed through workshops, side events, and field days.
REPEAT closely cooperates with the WETSCAPES project addressing fen peat formation in Northeast-Germany. The German part of REPEAT is funded by the Deutsche Forschungsgemeinschaft (DFG).

WETSCAPES (2017-2020)
The joint research project WETSCAPES works on understanding turnover and exchange of matter in wetlands to foster better land management, climate adaptation and protection of water bodies. The objective of the large-scale WETSCAPES project is to develop scientific foundations for a sustainable management of degraded and

then rewetted wetlands. Within WETSCAPES, the production and decomposition of above- and below-ground biomass in temperate wetlands will be quantified, with a special focus on root processes. These are key factors in the overall assessment of the carbon budget, because primary production of plants determines the amount of carbon input into these wetlands. Particularly important for the formation or degradation of peat, the most important carbon store, is the growth and turnover of root biomass. However, these factors are understudied in the wetland types in question. Destructive and non-destructive measurements will be used, both in the field and in a controlled mesocosm experiment. The project is funded by the Programme for Excellence in Research Mecklenburg-Western Pomerania for a duration of 4 years (2017 to 2020). It will deal with research questions on following topics:

Biomass: productivity of above and underground biomass and decay rates linked with rewetting and site management;

Mikrobiome: integration with biotic and abiotic contexts, i.e. concerning methane emissions, seasonal dynamics, microbial activities;

Paleoecology: characterisation of macro- and microscopic biomass degradation products, how much peat has vanished since drainage and did peat accumulate since rewetting;

Water regime: Quantification of water regime components, incl. capacity terms under different water management scenarios and vegetation types; water and nutrient fluxes with adjacent systems;

Substance cycle: C, N, P, S cycles connected with rewetting and management, strategies for sustainable use and development of fen sites (i.e. sink function) based on understanding of substance conversion;

Substance transport: defining transport characteristics of peat with different degradation rates;

Carbon exchange: quantification of gaseous carbon exchange in different fen types, quantification of reduction potential of rewetted peatland, investigation of production and emission pathway in order to define impact of water management (drained, rewetted) und management on THG-emissions, understand production- and emissions behaviour connected with rewetting, develop recommendations for rewetting management and climate smart land use;

Nitrogen exchange: understanding of peat mineralisation into mineral nitrogen and nitrogen gases, quantifying N_2O-emission from fens linked with rewetting and sites, distinction between microbial production paths of N_2O with new isotopic methods, quantification of N_2O sink function of rewetted peatlands;

GHG: quantification of GHG-exchange, reduction potential of rewetted peatlands and relation to biota;

Setting up of research data infrastructure;

Remote sensing: development of indicators for relevant environmental effects (esp. substance leakage) from drainage and rewetting;

Land use change: assessment and quantification of landscape substance cycle changes during time through comparison of historical peatland use and recent land use on peat.

Literature

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Links

https://www.wetscapes.uni-rostock.de/
https://botanik.uni-greifswald.de/experimentelle-pflanzenoekologie/projekte/wetscapes/
https://botanik.uni-greifswald.de/experimentelle-pflanzenoekologie/projekte/repeat/
http://www.stalu-mv.de/vp/Themen/Naturschutz-und-Landschaftspflege/EU-Life-Projekte
http://gut-darss.de/
http://www.schatzküste.com/schatzkueste/
www.paludikultur.de

Excursion 5

SPHAGNUM FARMING AND CULTIVATION OF SUNDEW, PEAT EXTRACTION, RESTORATION, PLANT CULTIVATION EXPERIMENTS WITH *SPHAGNUM* BIOMASS (NEAR TO OR IN OLDENBURG, LOWER SAXONY)

Matthias Krebs | Greta Gaudig | Ludger Thedering | Josef Gramann | Winfried Temming

Meeting point | Bus station (parking space for buses at the Karl-Marx-Platz/small roundabout traffic next to the pedestrian underpass)

Schedule

Start	End	Action	Comment
06:00	06:15	register, boarding the bus	hand out excursion guide
06:15	12:00	Bus transfer	explanation of the program, description of the landscape and current utilizations of bogs
12:00	12:30	field lunch	
12:30	14:30	Sphagnum farming field study site in the peatland 'Hankhauser Moor'	cultivation of *Sphagnum* (production cycles, management), research on implementation, ecosystem services like greenhouse gas emissions, and biodiversity, cultivation of sundew (*Drosera rotundifolia*)
14:30	15:00	Bus transfer to Ovelgönne	
15:00	16:00	Visit of peat extraction and restoration fields of the peat company 'Gramoflor'	different techniques of peat extraction (block cut, 'upper and subfield process' developed by Gramoflor, starting restoration during peat extraction (milled peat) by spreading *Sphagnum* mosses in the subfields, peatland restoration after peat extraction
16:00	16:45	Bus transfer to Oldenburg, Coffee break	
16:45	17:45	Visit of the Floragard company	application of peat as raw material for growing media in horticulture, marketing, plant cultivation experiment on Poinsettia with *Sphagnum* biomass in the greenhouse, visit of the laboratory for quality control of substrates
17:45	23:00	Bus transfer to Greifswald	

Route of excursion 5

General Introduction

The sites of the excursion 5 are situated in the northwest part of Germany, in Lower Saxony, close to or in the city Oldenburg (Figure 1).

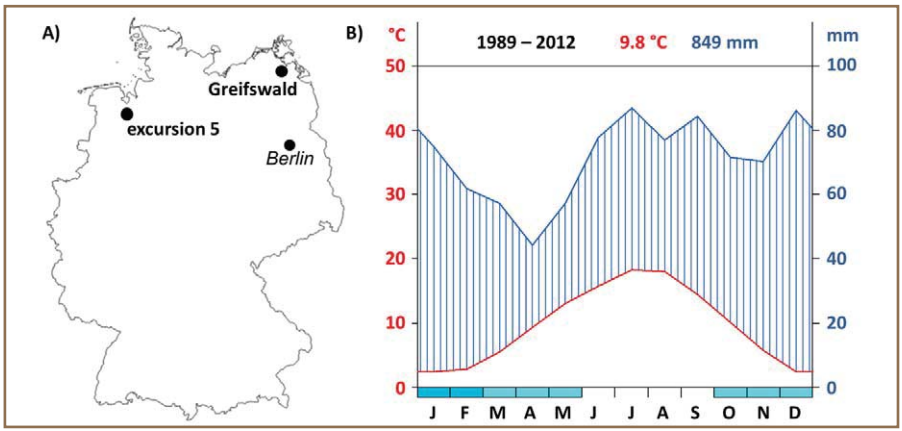

Figure 1: A) the location of the sites of the excursion 5 in Germany, near the city of Oldenburg, Lower Saxony and B) the climate graph for the Sphagnum farming study site in the peatland 'Hankhauser Moor'. The left hand axis is the mean day temperature (°C) and the right hand axis is precipitation (mm calendar month^{-1}). Dark blue stripes present the months where frost events certainly occur, light blue those where frost may occur.

Similar to the excursion sites in Mecklenburg-Western Pomerania the northwest part of Germany was shaped by the last glaciation and thus characterized by deposits of ground moraines, mainly sandy boulder clay or till, which were partly covered

by drifting sand and river deposits. The last glaciation (Saale glaciation) ended 130,000 years b.c. in contrast to Mecklenburg-Western Pomerania, where the Vistula glaciation ended 10,000 years b.c.
After the glaciation large areas paludified and fens and in particular bogs developed. The northwest part is the main distribution area of bogs in Germany (Figure 2A), and consequently the region with the main peat extraction activities.
This region is characterized by humid oceanic (atlantic) climate (Figure 1B).

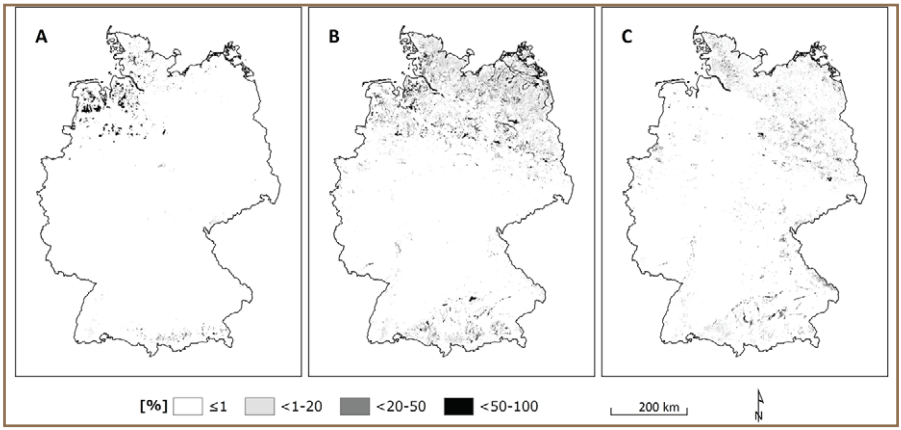

Figure 2: Abundance of organic soils in Germany (%) with A= bog soil, B=fen soil, and C=organic soils with < 30 cm peat (after Roßkopf et al. 2015).

Bog utilisation in northwest Germany

(main information from Trepel et al. 2017)
In medieval times bogs were used for small-scale peat cutting. *Sphagnum* peat was used as litter, while black peat was mainly used as fuel. At the end of the 17th century large bog cultivation started and land use on peat soils became more intensive. In the 19th and beginning of 20th century peat cutting increased in large mire complexes. Remarkable was the buck wheat fire cultivation on bogs, which caused substantially air pollution by smoke. This led to the establishment of the Mire Experimental Station Bremen (in northwest Germany) in 1877, where peatlands and peatlands utilisation was investigated. In particular the 'German raised bog cultivation' (Deutsche Hochmoorkultur) was developed and studied. Bogs were mainly used as grassland and to a small extent as arable land. Before the Second World War peat cutting changed from manually to industrial extraction techniques. The agricultural use was intensified as well with more effective drainage systems in particular during the 1950- 1970s. The rapid loss of natural bog areas led to the 'Moorschutzprogramm' (program for peatland conservation; part 1- 1981 and part 2- 1986) of Lower Saxony, where priority areas for peat extraction and for nature conservation as well as the restoration by rewetting of cut-over bogs were specified. Major aims were to protect around 50,000 ha not extracted and 31,000 ha extracted bog areas as well as several small bogs as nature conservation sites.

Peat extraction decreased over the last 30 years and will substantially decrease within the next years as the weakly decomposed peat ('white peat') and for horticultural purposes most valuable constituent is getting exhausted. Moreover, it becomes more difficult to get permits for extraction due to policy changes and refusal by local populations.
Recently most large bog complexes are destroyed by peat extraction and reclamation of agriculture and land use intensification. Nowadays the total bog area in Lower Saxony is around 208,000 ha and only < 1 % is in a natural state. More than 50 % of the bog area is agriculturally used including 44 % bog grassland and around 8 % for peat extraction (MU Niedersachsen 2015).

Sphagnum as an alternative to peat in growing media

To cover the growing demands from world-wide urbanisation, the cultivation of vegetables, fruits and flowers takes place in pre-prepared growing media, consisting mainly of weakly decomposed *Sphagnum* peat ('white peat', also known as 'blond peat' and, confusingly, 'peat moss') which is extracted from peatlands. Currently, peat provides 86 % of the raw material required by the European Union for horticultural substrates and 92 % of the German demand. In Germany, approximately 4 million cubic metres of white peat is used annually for professional horticulture and hobby gardening. In contrast the stocks of white peat in most countries of western and central Europe are largely depleted, and living bogs have become so rare that the few remaining examples are strictly protected. Thus the availability of peat becomes limited, and the growing media industry is forced to source it from ever more remote areas. Consequently there is an urgent need to develop sustainable alternatives for peat not only from ecological but also from economic and social point of view.
The most promising alternative is *Sphagnum* biomass as an environmentally friendly and high quality raw material for horticulture (Gaudig et al. 2014). Its use as a raw material for growing media in modern professional horticulture has been successfully tested and in some cases demonstrates even better results than the peat-based substrates developed over many years (Emmel 2008, Blievernicht et al. 2013).

What is Sphagnum farming?

Sphagnum farming is the sustainable production of non-decomposed *Sphagnum* biomass on a cyclic and renewable basis. Cultivation of *Sphagnum* ('Sphagnum farming') on rewetted bogs, including diaspore production, establishment, optimization of site conditions, productivity, and regeneration after harvest, has over the last decade extensively been studied by the University of Greifswald in cooperation with various research and industrial partners (see www.sphagnumfarming.com). In greenhouse and field trails prospects of Sphagnum farming were investigated for different former land use types like cut-over bog and bog grassland.
It can be concluded that Sphagnum farming, in particular on former bog grassland, is a promising example of paludiculture, which allows agricultural use of wet peatlands while halting degradation of the peat layer. In addition to biomass production,

paludiculture provides a range of other ecosystem services including climate regulation, water purification/nutrient retention, regulation of the water cycle, and provision of habitats for specialised biodiversity.
Research on Sphagnum farming started in 2004 both in Germany and in Canada. Worldwide the idea of Sphagnum farming attracts interest and research into its implementation has started in various other countries, including Finland, Ireland, Poland, Chile, or the Baltic countries. For large-scale implementation, at least in Germany, several challenges has to be solved, among others production of seeding material (diaspores), adjustment of legal and policy regulations, and development of *Sphagnum* based substrates.

Excursion sites

Sphagnum farming site in the peatland 'Hankhauser Moor'

The Sphagnum farming field site was installed by the peat company Torfwerk Moorkultur Ramsloh GmbH & Co. KG in May 2011 at the peatland 'Hankhauser Moor' near to Oldenburg, Germany (N 53°15.80' E 08°16.05'). This area is strongly degraded after decades of intensive use as grassland for dairy farming with deep drainage, leading to 1 m subsidence since 1958. Recently the region is situated 0.5 m below the sea level and drainage water has to be pumped out actively to the North Sea. For installation of the trials on over 4 ha (10 acres) the upper highly mineralized peat layer (~30 cm) was removed and used for constructing dams resulting in 10 m wide production strips bordered by irrigation ditches. After site preparation Sphagnum fragments were spread on the bare peat and subsequently covered with straw (Figure 3). After installation the site was rewetted. Irrigation water is pumped from the adjacent 'Schanze' stream, east of the study site, which drains the entire surrounding territory.

Figure 3: Installation of a large-scale Sphagnum farming field in NW Germany by the peat company Moorkultur Ramsloh GmbH & Co. KG (Hankhausen, spring 2011, left photo) and Sphagnum farming field in Hankhausen 1.25 years after installation (right photo). Photos: S. Wichmann

1.5 years after initial establishment *Sphagnum palustre, S. papillosum* and *S. fallax* already covered 95% of the area with mean lawn height of 8.3 cm (maximum 22.4 cm, Figure 3). *Sphagnum* productivity is high with a dry mass of around 8.7 t ha^{-1} yr^{-1} after the lawn establishment.
Five years after field installation first mechanical harvest of the *Sphagnum* mosses was conducted in 2016 the peat company Moorkultur Ramsloh GmbH & Co. KG. An excavator stood on the causeway and cut the mosses with a long arm and mowing bucket. Two third of the upper *Sphagnum* mosses were cut as former experiences showed that residual *Sphagnum* stems left regenerate fast. The material was directly spread to newly prepared fields to enlarge the cultivation area to 14 ha (Figure 4).

During the excursion you can see the different stages of a *Sphagnum* culture:
- Establishment: *Sphagnum* lawn one year after its installation in June 2016,
- Growth: a six years old growing and high productive *Sphagnum* culture
- Regeneration: *Sphagnum* mosses regenerating after harvest one year ago.

Up to now the site in the peatland 'Hankhauser Moor' has convincingly proven the feasibility of large-scale Sphagnum farming already during the establishment phase, and also with the subsequent high *Sphagnum* biomass productivity. The pilot site now allows developing methodologies and testing machines for further upscaling cultivation and harvest of *Sphagnum* biomass.

Figure 4: Sphagnum farming site in the peatland 'Hankhauser Moor' with areas installed in 2011 (right side at the picture) and in 2016 (upper left side at the picture). Three *Sphagnum* strips (installed in 2011) were harvested in 2016, photo: T. Dahms and S. Busse, April 2017.

The following main research topics are continuously assessed for the different stages of the *Sphagnum* culture, and main results will be presented during the excursion:
- establishment and development of *Sphagnum* species on former bog grassland,

- effects on biodiversity (plant species (Gaudig & Krebs 2016), spider fauna (Muster et al. 2015)),
- risk potential of growth inhibitory factors,
- hydrological requirements of *Sphagnum* cultures (water budget),
- nutrient stoichiometry of *Sphagnum* cultures due to nutrient rich irrigation water (Temmink et al. 2017)
- balancing the fluxes of greenhouse gas emissions of the production areas, the irrigation system and causeways of a Sphagnum farming site (Günther et al. 2017),
- technical feasibility and
- economy of Sphagnum farming (establishment costs of a *Sphagnum* culture – Wichmann et al. 2017).

Furthermore many sundew (*Drosera rotundifolia*) plants are spontaneously growing in the *Sphagnum* culture. Recently *Drosera* species are used for medicate respiratory diseases with medicinal products from dried above-ground plant parts. The plants are mainly collected from wild populations in the peatlands, while all *Drosera* species are endangered now in Europe (Baranyai & Joosten 2016). Prospects of *Drosera* cultivation in combination with Sphagnum farming is investigated at the Sphagnum farming site in Hankhausen. Research of germination, survival, biomass growth and content of medicinal ingredients is done at the University of Greifswald. Information can be given during the excursion.

Peat extraction and peatland restoration

We will visit peat extraction sites of the peat company Gramoflor in Ovelgönne. There we will see different techniques of peat extraction. Recently peat is solely extracted at agriculturally pre-used and degraded bogs like bog grasslands. Here the upper strongly mineralised peat layer is removed and the extraction of the weakly decomposed *Sphagnum* peat ('white peat') starts with the block cut method, where bricks (size around 35 x 15 x 15 cm) to a depth of around 80 cm are cut mechanically. The blocks are piled in long rows to be dried by sun and wind. This process takes 1-2 years. Peat extraction is then continued by the 'milled peat' method with 'upper and subfield process' developed by Gramoflor (Figure 5). The peat is extracted at strips with a width up to 15 m for 4 years down to leave at minimum a 50 cm deep residual peat layer. Peat extraction then continues left and right sided to the strip to the similar depth, reaching an overall width of up to 30 m. During this period the strip, where the extraction started, is rewetted and *Sphagnum cuspidatum* and *S. fallax* are spread in small amounts to initiate restoration of the cut-over peatland area. This procedure continues until nine years (Figure 5). While the margins are extracted, the residual peat areas after extraction are step by step rewetted. During the excursion we will see a four years old 'upper and subfield' site and an older restoration site.

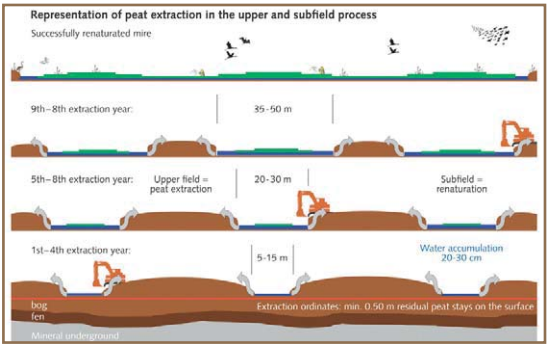

Figure 5: Peat extraction and restoration of cut-over bog by the 'upper and subfield process', Gramoflor.

Plant cultivation experiments at Floragard company

Since nearly 100 years Floragard Vertriebs-GmbH in Oldenburg has developed, manufactured and distributed potting soils and substrates. Floragard has an archive with more than 3000 substrate recipes for a wide range of applications, requested by customers like gardeners to achieve optimal growth performance. The substrates are used for hobby as well as for professional gardening.

During the excursion here we will get an introduction about the manufacturing of substrates and different applications. It will be illustrated with a guided tour to see the laboratory, where constantly the quality of single substrates recipes is tested.

Figure 6: a) Ericaceous plants ready for sale, potted in 0 – 25 – 50 – 75 – 100 % *Sphagnum* biomass (left to right, admixture of slightly humified *Sphagnum* peat), b) Azalea "Sachsenstern" potted in 100 % *Sphagnum* biomass (Ueber & Gaudig 2014, photos: E. Ueber).

On the basis of promising results of other plant cultivation experiments (see above, Figure 6) also Floragard company is testing *Sphagnum* biomass based substrates. In the greenhouse we will have a look these experiments with Poinsettia plants.

Further reading

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Ueber, E. & Gaudig, G. 2014. Azerca-Kulturen: Torfmoos als Substratbestandteil geeignet. In: TASPO Nr. 19.

Links

www.sphagnumfarming.com
www.mires-and-peat.net (Volume 20 - Special Volume: Growing Sphagnum 2017)
www.moorkultur-ramsloh.de/
www.gramoflor.com
www.floragard.de/en/
http://www.gret-perg.ulaval.ca/

Excursion 6

PALUDICULTURE PLANTS AND SALT MEADOWS NEAR GREIFSWALD

Susanne Abel | Claudia Oehmke | John Couwenberg | Dierk Michaelis

Meeting point | Entrance of the Botanical Garden of Greifswald University, Münterstraße 2

Schedule

Start	End	Action	Comment
08:30		Meeting at the Botanical Garden	Registry
08:30	10:00	Botanical garden Greifswald	Tour through the exhibition of paludiculture plants. Description of plant characteristics, biomass use and cultivation methods
10:15	10:45	Bus transfer to Karrendorf	
10:45	12:45	Karrendorfer Wiesen	History of the area, land use and rewetting measures of the coastal flood peatlands
12:45	13:00	Bus transfer to Greifswald	End of excursion

Route of excursion 6

Introduction

Part I

The Botanical Garden of the University of Greifswald was established in 1763 by Samuel Wilcke (1704–1773). In his education beside theology he studied natural history with Carl von Linné at Uppsala University in Sweden. At the beginning the garden was placed between the University main building (Rubenow square) and the old town wall as „hortus medicus“ for medicinal plants, but one year later it was given the name „hortus academicus“ because of its botanical character and the growing importance of Botany as independent scientific discipline. In 1886 the garden was moved to the recent area near the train station. Palm-, Cold- and Warmhouses were established. These buildings are the centre of the recent Botanical Garden with 16 greenhouses and an exibition area of 14,000 qm. Half of it is accessible for visitors. Unfortunately the large palm house, built between 1884-1886, is closed for the public since 2014. The building was used for 130 years, even during the war the plant collection could be preserved. But today the steel construction is getting weak and for safety reasons access is not allowed for visitors. It is necessary to reconstruct the building, which will cost around 2.5 million Euro. The friends and supporters of the Botanical Garden association is collecting money during special events, such as dance evenings, guided tours and to support the university and to help to preserve the palm house also for future generations.

Paludarium

The exhibition on paludiculture plants was opened at the Botanical Garden of Greifswald University in July 2017. For this the already existing `Paludarium` (exhibition of wetland plants) has been updated and extended by plant containers with additional important paludiculture plants and explanatory signs.
Three categories of plants are shown:

I) plants that can be used in paludiculture and with wich already positive experiences have been made = paludiculture plants
II) plants, which may play a role for paludiculture, but for which certain properties still have to be researched (effect on greenhouse gas emissions, peat conservation) = potential paludiculture plants
III) useful wetland plants, whose cultivation in peatlands is not peat conserving (e.g. annual rotation necessary, belowground plant parts are used or constant high water tables are not tolerated).
In total more than 40 plants are described on individual signs with an illustration of the plant and information on its use. In addition, a large information board introduces the concept of paludiculture and the history of research on paludiculture in Greifswald. More than 150 years ago, the founder of the botanical museum Julius Münter published an article about *Zizania aquatica* and mentioned a potential cultivation on the "lower meadows". Since 1995 14 projects have been conducted by the partners of the Greifswald Mire Centre about paludiculture on fens or bogs.

Opening of the exhibition of paludiculture plants in the Botanical garden Greifswald.

Part II
Karrendorfer Wiesen: Introduction
The "Boddenlandschaft" of Vorpommern is known as "a coast with two coastlines". The Bodden, shallow water bodies originating from the Holocene transgression of the Baltic Sea, line up in the interior of the outer coast and form a second coastline. The shore of the Bodden provides a unique habitat with low salinity and no tidals, while the outer coast is dominated by cliffs, dunes and sandy beaches, the inner shoreline is dominated by salt meadows and reeds. Conditions for plant and animal life in the salt marches are characterised by changing salinity due to irregular floods, we thus find here a number of well adopted and rare species. Besides that, salt meadows once functioned as a semi natural coastal protection. The trampling by grazing cattle and horses has strongly compacted the surface layer and thus allowed

the salt meadow peat to grow high above the mean sea water level. Since the 1960s diking and drainage has however destroyed most salt meadows along the Baltic Sea. In 1993, the removal of the dike around the Karrendorfer Wiesen polder re-exposed 360 ha of former salt meadows to the flooding regime of the Baltic Sea. Within a few years salt meadow species re-occupied the formerly intensively used agricultural lands and the salt meadows started to function again as near natural coastal protection. Within 10 years, overexploited and degraded agricultural lands changed into a paradise for birds and birdwatchers alike.

Site description

The Karrendorfer Wiesen (Wiesen= meadows), 10 km north of Greifswald, are part of the morainic plain of Vorpommern. The morainic till in the underground slightly undulates and rises from below mean sea level in the northern part to 2-3 m above mean sea level in the southern parts. About 67 % of the area is covered by peat, humus-rich sands or alluvial mud. The basis of the peat layer usually consists of reed (*Phragmites*) peat that developed during the last stages of the Baltic Sea Littorina transgression after 6000 BP. This reed peat is covered by a peat layer consisting of radicels with abundant diatoms and seeds of *Juncus gerardi*. The latter peat was formed as a result of grazing of cattle and horses, that started as a function of the general increase in human activity in the region since the 13th century AD. This grazing changed the original reeds progressively into salt meadows dominated by *Juncus gerardii, Puccinellia distans, Festuca rubra, Triglochin maritimum, Trifolium fragiferum, Glaux maritima* and *Plantago maritima*.

Reed peat only deposits at or below the mean sea water level, its accumulation thus depends on slowly rising relative sea water levels. Salt meadow peat can however grow significantly above the mean sea water level: compaction by grazing cattle and horses results in decreasing pore size and thus increasing capillarity. The wetness at surface thus increases and oxidation of plant material is reduced. By this “anthropo-zoogenic” peat formation (Jeschke 1987) the salt meadows could grow up over the sea level to constitute a significant coastal protection.

Use and exploitation

The late 17th century Swedish fiscal register map shows that the lowest parts of the Karrendorfer Wiesen were used as pasture land, higher areas as hayfields, and the highest elevations (> 1 m above mean sea water level) for arable farming. The area was already surficially drained by shallow ditches, but no dike existed. This already resulted in peat mineralization, subsidence, and consequently more frequent flooding. To prevent flooding at least during the growing season, a summer dike was built in 1850/51.

This dike was destroyed during the heavy storms of 1872 and 1874 and was rebuilt only in 1910. Increased yields allowed higher cattle densities of about one unit per ha in the early 1900s. Although two wind driven (since the 1920s) and several electrical (since 1956) pumping stations allowed active drainage of the Wiesen, the

brackish Bodden waters continued to enter the area during high floods, influencing the vegetation. Around 1930 the area was largely used as grassland and arable land was rare.

After 1936, land use was temporarily suspended. In that year, the nearby island of Koos was bought by the Ministry of Aviation (Reichsluftfahrtministerium) and in the following years used as a target for practising bombing. The Karrendorfer Wiesen became a dangerous and forbidden area, grassland use was abandoned and drainage constructions fell into dispair. Not until 1953 a cooperative farm started to use the Karrendorfer Wiesen as pasture and grassland again. The so-called complex melioration (German: Komplexmelioration) from 1971-1974 permanently cut off the Karrendorfer Wiesen from the Baltic Sea, except for a small fringe. The agricultural use was once more intensified; the main area was used as intensive grassland and temporarily as arable fields. To reduce the abundance of less productive grasses (e.g. *Elitrygia repens, Holcus lanatus*) the meadows were regularly ploughed and cultivated with selected grasses. Despite high fertilization, harvests remained low. As a result of strong peat oxidation, some areas subsided (partly below the mean sea level) and were difficult to drain. In 1988/1989, just before the "Wende", the drainage system was fully renewed and the meadows once more ploughed. In 1990/91, however, all use was abandoned.

Restoration

The restoration of the Karrendorfer Wiesen only came into scope after the political and economic changes in the GDR. The interest in agricultural use rapidly decreased as relatively high costs and small yields no longer brought any profit. The cooperative farm was closed down in 1991 and other farmers were not interested in pursuing use of the Karrendorfer Wiesen. In addition, the state reduced the priority of the dike and handed it over into the responsibility of the regional water association that was hardly capable to pay for dike maintenance pumping costs.

The new state and regional nature conservation administrations made good use of the situation and initiated the restoration by allowing a natural flooding regime. Before the old dike was removed, a new dike protecting the village of Groß-Karrendorf was installed and the road dam that crosses the area towards the island Koos was hightened. In autumn 1993 the old dike was removed over a length of 6.4 km and the former pattern of creeks recognisable on aerial photographs from 1937 reshaped. This was the first time that a dike had intentionally been opened in Mecklenburg-Western Pomerania. An area of 360 ha plus the nearby Kooser Wiesen of 700 ha now again experience the natural coastal flooding regime of the Baltic Sea.

The major vegetation type today is *Juncetum gerardi* Nordh. Its typical species poor variant with *Juncus gerardii, Triglochin maritimum, T. palustre* and *Plantago maritima* occupies the lower parts. On the higher elevations a richer variant with *Trifolium fragiferum, Lotus tenuis* and *Leontodon autumnalison* is found. At the shore, were grazing is less intense, *Phragmites australis* and *Bolboschoenus maritimus* dominate. In several ditches, *Hippuris vulgaris* occurs. Because of the low salinity typical halophytes like *Halimione portulacoides, Salicornia procumbens* and

Puccinellia maritima that still occur in the western Baltic Sea, are missing.
Since restoration, Karrendorfer Wiesen can only be used for grazing, but the size of usable area has remained the same. Furthermore, restoration has strongly reduced the costs of fertilisation, pumping and dike maintenance. In 2006, the cattle of two farmers graze on the meadows in low intensity with less than 1.5 animals per ha. Irregular distribution of grazing intensity leads to both overgrazed areas with soil and vegetation damage and undergrazed areas where reeds suppress salt meadow vegetation development. Some cattle suffers from poor-quality grass and calves even died from Selenium deficiency.

Current developments

In 2016 the Michael Succow Foundation received property rights for 365,07 ha of the Karrendorfer Wiesen as part of the second tranche of the Natural Heritage programme "Nationales Naturerbe". Within this program protected areas owned by state authorities have been transferred to nature protection foundations and associations (e.g. DBU, NABU and Succow Foundation). Although the restoration measures in 1993/94 already initiated a near natural development of the coastal area of the Karrendorfer Wiesen, but the re-establishment of additional salt grasslands in the central, eastern and southern parts of the area with extended reeds, open water and muddy areas needs further efforts. The management plan for the FFH site DE 1747-301 (2011) evaluates the current state of the habitat type (LRT 1330) of the Karrendorfer Wiesen by C – unfavourable. To improve the conditions for salt grassland vegetation, the Michael Succow Foundation will

- restore the functionality of the tideways and narrow channels
- reinstall the connection of the northern and southern parts of the dam to Koos island
- improve discharge from and drying of muddy non vegetated sites.

Additionall infrastructural measures (installation of fords and fences) will improve the accessibility as precondition for further intensification of grazing and for summer mowing of reeds for reducing the cover of reeds.
A predator-management will be established to improve the conditions for waders and grassland birds. Also measures for the guidance of vistors will be taken. The realisation will start by the end of 2017.
In the interdisciplinary joint project WETSCAPES (2017-2020) Karrendorfer Wiesen were chosen as one of its core sites to study matter turnover processes at peatlands and coastal sites as a basis for improved land use, climate and water protection.

Karrendorfer Wiesen (photos: W. Wichtmann)

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Abel, S., Couwenberg, J., Dahms, T. & Joosten, H. (2013) The Database of Potential Paludiculture Plants (DPPP) and results for Western Pomerania. – Plant Div. Evol. 130: 219–228

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Theuerkauf, M., Couwenberg, J. Joosten, H., Kreyer, D. & Tanneberger, F. (eds.) (2006): New Nature in North-Eastern Germany. A Field Guide. Institute of Botany and Landscape Ecology, Greifswald, 125 p.

Links

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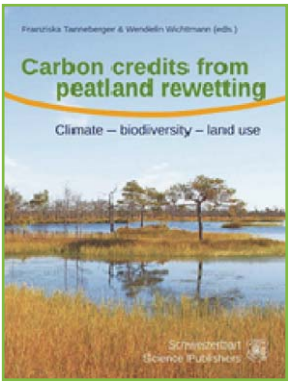
PUBLICATIONS

Peatland publications from Greifswald



Belarus ranks 8th among the world's countries in terms of peatland CO_2 emissions and occupies 3rd place in CO_2-emissions per unit land area. In recent years, tens of thousands of hectares of drained peatlands in Belarus have been rewetted. This volume provides a synthesis of the challenges encountered and solutions adopted in a pilot project conducted in Belarus between 2008 and 2011. It presents data and conclusions from the project and relates basic principles to advanced applications, integrating science and politics, ecology and economy. The experiences and recommendations for peatland restoration set forth in this volume will inspire practitioners, land-use planners, scientists and politicians alike. A russian language edition of this book is also available.
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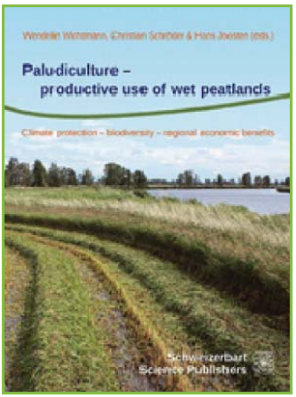

The volume introduces paludiculture as a novel land use practice for the production of biomass, which is further able to reactivate or sustain a wide variety of ecosystem services impaired by peatland drainage. Biomass from wet peatlands is useful for various applications: as fuel and raw material, food, fodder and medicine. The authors discuss and evaluate the ecosystem services and economic feasibility of various land use options..
The book provides extensive information for practioners and scientists as well as decision-makers in politics, management, and explains the principles of wise peatland management, encouraging the worldwide implementation of paludiculture as a unique form of sustainable utilisation of organic soils. This book is also available in German language.
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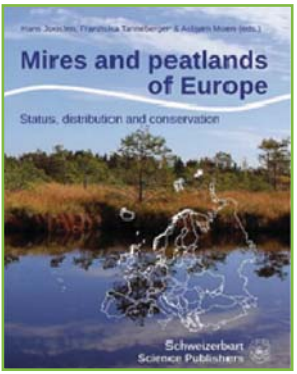

This book provides the first comprehensive and up-to-date overview of mires and peatlands in biogeographic Europe. Authored by 134 mire specialists, the extensive volume describes mire and peatland types, terms, extent, distribution, use, conservation, and restoration, individually for each European country and in an integrated manner for the entire continent. The European continent features an impressive variety of mires and peatlands. Polygon, palsa, and aapa mires, concentric and eccentric bogs, spring and percolation fens, coastal marshes, blanket bogs, saline fens, acid, alkaline, nutrient poor, nutrient rich: the peatlands of Europe represent unique ecosystem biodiversity and harbour a large treasure of flora and fauna typical of peat forming environments.
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9 Networking evening @ST. Spiritus