WET AGRICULTURE AND FORESTRY (PALUDICULTURE) ON REWETTED PEATLAND

Peatlands are space efficient organic soil carbon pools. Wet peatlands with peat forming vegetation, mires, are a carbon sink, where the up taken CO_2 is sequestered in the dead organic matter which is conserved under water saturated conditions in their organic soils (peat). In the last 10,000 years mires have efficiently removed CO_2 from the atmospheric pool cooling the average global temperature by 0.6°C (Frolking et al. 2006; Frolking and Roulet 2007; Yu et al. 2011). While occupying only 3% of the global land cover they store 600,000 Mt of Carbon (Yu et al. 2010), twice as much as in all forests which cover 30% of the land on earth (Joosten 2009; Scharlemann et al. 2014). Considering efficient climate change mitigation measures it is essential to conserve the carbon storage and sink function of the still 88% of remaining global pristine mires (UNEP 2021).

Today drained, used and abandoned peatlands worldwide make only approximately 12% of the original pristine mire area (0.4% of the global land cover) but contribute annually approximately 2Gt of CO_2 emissions from peat decomposition what makes 5% of all human made annual GHG emissions (Barthelmes et al. 2018). Rewetting of peatlands is an efficient method to reduce and on the long term to stop emissions and establish new permanent carbon sink systems. Avoidance of further peatland reclamation by drainage and conversion to conventional agricultural or forestry schemes or for exploitation of peat resources and the rewetting of drained peatland play an essential role in nature-based solutions by preserving environmental services provided by wet peatlands (Tanneberger et al. 2020).

Despite methane emissions from rewetting measures rewetting of all peatlands is a central element of a transformation pathway in the land use sector (Günther et al. 2020, (https://www.youtube.com/watch?v=9fR8oxjxpTQ)) to meet 2045 climate targets of the EU.

In order to avoid Methane peak emissions rewetting measures can, after careful consideration of impacts, be optimised following the recommendations of Quadra et al. (2023):

1. Removing aboveground biomass before rewetting
2. Removing 5-10 cm of topsoil with living roots
3. Avoiding long-term flooding during the growing season
4. Implement controlled and slow, gradual rewetting and
5. Foster the growth of peatland specific plants

Rewetting is not necessarily bound to abandonment of utilisation. By establishing high water levels in formerly drained peatlands implementation of paludiculture, the wet agricultural or silvicultural use of peatland, holds potential to contribute to reach national CO_2 emission reduction targets (Tanneberger et al. 2020), which can since 2020 be reported following new accounting rules that are based on country specific national inventories (Barthelmes et al. 2015).

What is Paludiculture?

Paludicultures aim at agriculture, forestry or renewable energy practices adapted to wet and rewetted peatland (Wichtmann et al. 2016, Hohlbein 2022, see also Figure 1). They realize productivity while preserving the organic carbon stored in the peat deposit. Therefore, permanent waterlogging and stable anoxic conditions during the vegetation period are essential. This is achieved by keeping mean water levels at or close to the soil surface (≤10 cm) and by avoiding practices that disturb the topsoil and root layer of the rewetted site.

Paludiculture uses spontaneously grown or cultivated biomass of adapted plant species from wet peatlands under conditions in which the peat is conserved or even newly formed (Wichtmann & Joosten 2007). This implies that utilisation options are restricted to the aboveground biomass from site adapted wetland species (leaves, stems, inflorescences, fruits, and seeds).

Technologies applied in biomass cultivation and harvest must be adapted to wet and soft soil conditions with minimised weight of the machines used, large contact area of the tyres or chains to the soil, reduction of crossings during harvest and transport, minimisation of shearing forces to avoid negative physical impacts on root and topsoil layer.

Depending on nutrient availability and pH value different vegetation can be used in paludicultures.

On Fen peatland (normally richer with nutrients and higher pH):

- Cultivation of reeds, for materials or energy fuels (Common Reed – Phragmites australis; Cattail - Typha angustifolia, T. latifolia)

Usage of wet meadow biomasses or mixed spontaneous grown or cultivated grassland (Sedges - Carex spp.; - Reed canary grass – Phalaris arundinacea)

- Usage of wet meadow biomasses or mixed spontaneous grown or cultivated grassland (Sedges - Carex spp.; -Reed canary grass – Phalaris arundinacea)
- Wet forestry for energy fuel wood or quality timber with adapted peatland tree species (Black alder – Alnus glutinosa, wetness tolerant willow species – Salix spp.)
- Medical plants cultivation (e.g. Comfrey – Symphytum officinale, Hemp-agrimony – Eupatorium canabinum; Gypsywort – Lycopus europeaus)

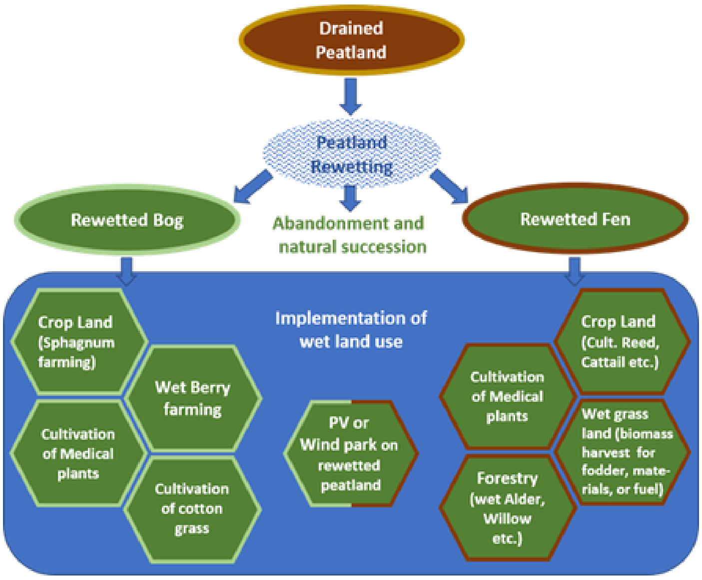

Figure 1: Overview on general land use options in rewetted peatlands. Site properties and water qualities after rewetting determine peatland type ("Bog", nutrient poor, acidic & rain water fed; or "Fen", nutrient- and base-rich & fed with mineral rich ground or surface water) and the possible land use options. Including rewetting without active establishment of paludiculture crops (abandonment and natural succession) and renewable energy options with photovoltaic (PV) and wind park on rewetted bog or fen sites or utilisation of paludiculture biomass for energy production, e.g. wet or dry fermentation for biogas production or for combustion in biomass heat- or heat- and power-plants.

- Technical approaches for renewable energy production with photovoltaic or wind energy generation can be aligned with paludiculture criteria if paludiculture water level targets and minimum impact on soil are realised. In a GMC position paper recommendation for PV on rewetted peatland is given (Hohlbein 2022).

On Bog peatland (normally nutrient poor and low pH):

- Cultivation of peat mosses, for horticultural substrates (Sphagnum spp. – Sphagnum farming)
- Wet berry farming (Cranberry - Oxycoccus macrocarpus; Mossberry – O. palustris; Cloudberry - Rubus chameamorus; Blueberry – Vaccinium angustifolium)
- Medical plants cultivation (e.g.Sundew - Drosera rotundifolia; Bogbean - Menyanthes trifoliata

Paludiculture provides multiple ecological and social benefits:

- Mitigation of land-based CO_2 emissions by reducing emissions from drained peatlands with rewetting measures that stop peat decomposition and therewith preserves the fossil carbon stock, and by substituting fossil resources, including peat, with renewable biomass.
- Adaptation to climate change by restoration of peatlands as water retention ecosystems on landscape level, stopping peat soil subsidence, stabilising coastal peatland systems against global sea level rise and coastal abrasion, providing local cooling effects by higher evapotranspiration in hot summers, buffering catchment-based river flood peaks and drought events.
- Generating innovative production and income perspectives in areas that would be severely deteriorated or even lost for production in future under a continuation of drainage-based peatland utilisation.

Paludiculture beyond that:

- Differs fundamentally from drainage-based conventional peatland use, which leads to huge emissions of GHGs and nutrients and eventually destroys its own production base through peat 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, 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 GHG emission reduction potential.
- Is a worldwide applicable land management system to continue land use on rewetted degraded peatlands. Various plants can be cultivated under wet conditions in the Holarctic (Abel & Kallweit, 2022).
- Is also a land use alternative for natural peatlands particular for regions where the increasing demand for productive land boosts the drainage of peatlands. Because of their vulnerable ecosystem services, pristine peatlands should at best be protected entirely. If land use on pristine mires is unavoidable, paludiculture should always be given preference over drainage-based land use.
- Paludiculture options can be diversified and optimised by establishing land use mosaics adapted to different rewetting perspectives due to existing slopes or macro-relief e.g. in a polder area (see Figure 2).

Economic viability of paludiculture is dependent on: 1) the infrastructural and logistical optimisation of the biomass harvest, and the distance to the biomass procession facilities 2) The sought kind of utilisation and the revenues that can be achieved with the biomass or the processed products (paludiculture value creation chains). High quality material products may have higher revenues than direct utilisation as fodder or energy fuel but are dependent on more complex multi stakeholder cooperation and market systems. 3) Viability finally depends on local/regional demands for specific biomass and the investment costs for establishment of paludiculture plant species, maintenance, harvesting, and processing facilities.

Is Paludiculture economically viable?

At present, there are no ready-made business plans for paludiculture approaches. Existing practices are often at pilot stage or deduced from established traditional land use practices in wetlands covering smaller niche

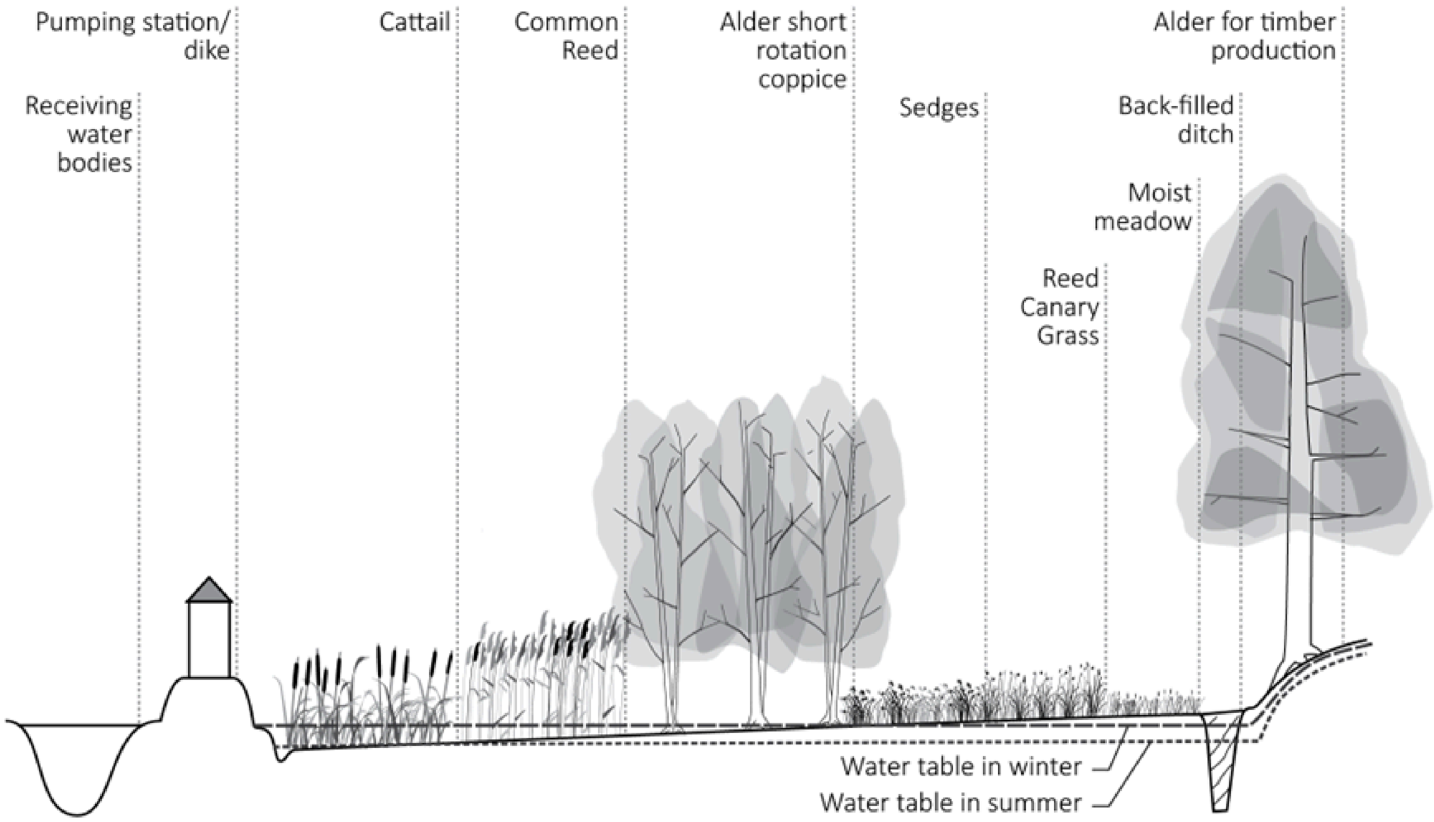

Figure 2: Mix of different land use options after rewetting of a peatland polder (from Schröder & Wichtmann 2016).

markets only, e.g. reed trade for roof thatch and board materials (Wichmann & Köbbing 2015). Existing figures from traditional or small-scale businesses can be used to estimate economic figures that are necessary for implementation of innovative paludiculture on larger scale. On local and regional scale market demands and distance between harvesting areas and secondary byers of biomass for production of further products play an essential role.

On EU common agricultural policy level (CAP) and national level of Member states little funding schemes are currently developed which would support paludiculture implementation as Climate change mitigation measures (CCMs) in the land use sector as the ambition in the CAP to stop funding of drainage-based peatland utilisation and subsidising rewetting and paludiculture practices comes to short (EEB 2022). Within large-scale and long-term paludiculture pilot site establishment missing links and gaps in value creation are currently under research. For example, in Germany the peatland rich federal states therefore are just implementing large-scale model and demonstration sites (MuDs) funded for ten years by the Federal Ministry of Food and Agriculture. The MuDs are coordinated and linked for cocreation of synergies and viable value chains with the super-ordinated project PaludiZentrale (link) at Thünen-Institute and Greifswald mire Centre partners Greifswald University and Succow Foundation.

Current Horizon calls (link) comparingly aim at implementation of large-scale demonstration sites in Europe.

On Baltic level projects funded by the European Climate initiative EUKI Paludiculture in the Baltics (link) & Carbon capturing by Baltic peatland farmers (link) promote paludiculture exchange, knowledge transfer and development of a Baltic paludiculture Network. In the current running EUKI carbon capturing by Baltic peatland farmers also development of guidance on practical and implementation level is ongoing.

Paludiculture in LIFE OrgBalt

In LIFE OrgBalt several model sites had been selected which might comply with paludiculture criteria and are under analysis to address CCM potential of paludiculture approaches. Long-term paludiculture management including environmental and economic monitoring can give better understanding and of paludicultures and their environmental and economic management in future.

Depending on rewetability and ensuring a limit of water table draw down during the vegetation period, there are different measures which hold good potential for climate friendly paludiculture management of formerly drained peatland sites under agriculture and forestry:

a) Measure LVC309 Semi-natural regeneration of clear-felling sites with Birch and Alder without reconstruction of drainage system.

Depending on efficiency of the remaining drainage infrastructure to meet paludiculture criteria active rewetting measures might be necessary to optimise surface near summer water levels in the site. Black Alder (Alnus glutinosa) is the preferred Species which could be used in wet short rotation coppices or in production of quality timber (Schäfer & Joosten 2005). Black alder shows good spontaneous regeneration capacities from fruitlets spread on bare soil after spring flooding.

b) Measure LVC311 Riparian buffer Zone in forest land planted with Black Alder.

If natural riverbeds with adjacent organic soils and high groundwater table would need drainage for conventional forestry, paludiculture with Black Alder is the best option to preserve soil carbon stock and improve river water quality by reduced nutrient input from peat degradation and shading of the water body.

There are also measures tested in LIFE OrgBalt which can be implemented under paludiculture standards but have currently on the market established or partly subsidised conventional schemes which frustrate economic competition of cultivated paludiculture forms and where drainage-based utilisation leads to lower management costs.

c) Measure LVC303 “Paludiculture – afforestation with Black Alder and Birch”.

Comparingly to measures b) and c) above if high water levels can be achieved with rewetting and stabilised over the whole rotation scheme this will have good chances to achieve environmental benefits. Compared to conventional drainage-based forestry management costs of the wet forest will be more cost intensive.

d) Measure based on data from LIFE Peat Restore (link) “Raising groundwater levels and growing berries, including blueberries, blueberries and cranberries, in wetlands”.

Cranberries have here the highest potential to be cultivated at nature near water levels of intact peatlands. But conventional berry farming uses drainage, chemical pest control and fertilisation schemes to improve productivity and use in some cases potential invasive cultural species (Karofeld et al. 2017). These factors frustrate achievement of paludiculture ecosystem services. This only make sense if it would be combined with strict control of compliance with target water levels. Current practice in Latvia is that berry farmers compete with peat extractors for drained cut over peat bogs with remaining layers of white peat to extend their production area to benefit from drainage infrastructure prepared by peat extraction.

Conclusions

Paludicultures are suitable land use approaches to stimulate and involve local actors in peatland rewetting for a transformation pathway towards carbon neutrality in the land use sector. In order to overcome pilot stage and proof efficiency for CCM and economic viability the main challenges are:

- Long-term analyses of effects of large scale paludiculture management on ecosystem services (water and climate regulation, biomass productivity and biodiversity development).

- Further development of production schemes (biomass cultivation, harvest and processing practices).
- Development of markets and value creation chains for the upscaling of paludiculture production.

Exchange between the currently international emerging large scale paludiculture pilots hold chances to gather needed experience to speed up the progression towards environmentally and economic sustainable paludiculture schemes.

Measures with paludiculture potential tested in LifeOrgBalt need to be monitored on long-term to ensure development and achievement of paludiculture criteria.

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