Paludiculture is paludifuture:

Climate, biodiversity and economic benefits from agriculture and forestry on rewetted peatland

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Growing global population, increasing prosperity in emerging economies and the exploding demand for biofuels have worldwide renewed the attention for peatlands.

Mosaic of summer cut, winter cut and not cut wet peatland areas in Peene Valley, Germany. Photo: B. Herold

Oil palm and pulp plantations are running unhindered over tropical peatswamps, peatlands in Europe are being re-drained for food and biofuel crops. Not only biodiversity is at stake: biofuel production on drained peatland generally generates far more greenhouse gases (GHGs) than it saves. Rewetting drained peatlands, in contrast, reduces emissions substantially. Even more emissions are avoided by paludiculture: by using biomass from rewetted peatlands to replace fossil raw materials and fossil fuels.

What is paludiculture?

Paludiculture (lat. '*palus*' = swamp), the cultivation of biomass on wet and rewetted peatlands, is an innovative alternative to conventional drainage-based peatland agri- and silviculture (Wichtmann & Joosten 2007). Ideally the peatlands should be so wet that peat is conserved and peat accumulation is maintained or re-installed. Paludiculture uses that part of net primary production (NPP) that is not necessary for peat formation (which may amount to 80-90% of NPP). In the temperate, subtropical

Tab. 1: Examples of biomass utilisation from wet peatlands in temperate Europe (changed after Wichtmann et al. 2000). Q* = demand for quality: ++ = high. + = medium, 0 = low).

Utilisation		Plant growth	Harvest	Q*
Agricultural	Ex situ fodder (hay, silage)	Wet meadows, reeds	Early summer	++
	In situ fodder (grazing)	Wet meadows, reeds	Whole year	++
	Litter	*Carex* meadows, reeds	Summer/autumn	0
	Compost	Wet meadows, reeds	Late summer	0
Industrial	Roofing material	Reeds	Winter	++
	Form-bodies	Wet meadows, reeds	Autumn/winter	+
	Construction/insulation	*Phragmites* reeds	Winter	++/0
	Paper (cellulose)	*Phalaris-Phragmites* reeds	Winter	+
	Basket-ware	Willow shrubs	Autumn	++
	Timber/furniture/veneer	Alder swamps	Frost	++
Energetic	Direct combustion and gasification	Alder/willow swamps, reeds	Autumn/winter	0
	Fermentation	Wet meadows, reeds	Early summer	+
	Liquid 'sun fuels'	Wet meadows, reeds	Whole year	0
Other	Officinal	Natural mires/plantations	Early summer	++
	Food	Natural mires/plantations	Summer/autumn	++
	Growing media	Peatmoss stands	Whole year	++

and tropical zones, i.e. those zones of the world where plant productivity is high, peat is generally formed by roots and rhizomes, and mires by nature hold vegetation of which aboveground parts can be harvested without harming peat formation. The quintessence of paludiculture is to cultivate plants that

- thrive under wet conditions,
- produce biomass of sufficient quantity and quality, and
- contribute to peat formation.

There is much commercial potential in using biomass from wet and rewetted peatlands (Tab. 1). Beside traditional agricultural uses for fodder and bedding, biomass can be used as a raw material for industry and for energy generation. On highly degraded nutrient-rich sites, planting of reeds or trees before rewetting can speed up the establishment of desired stands.

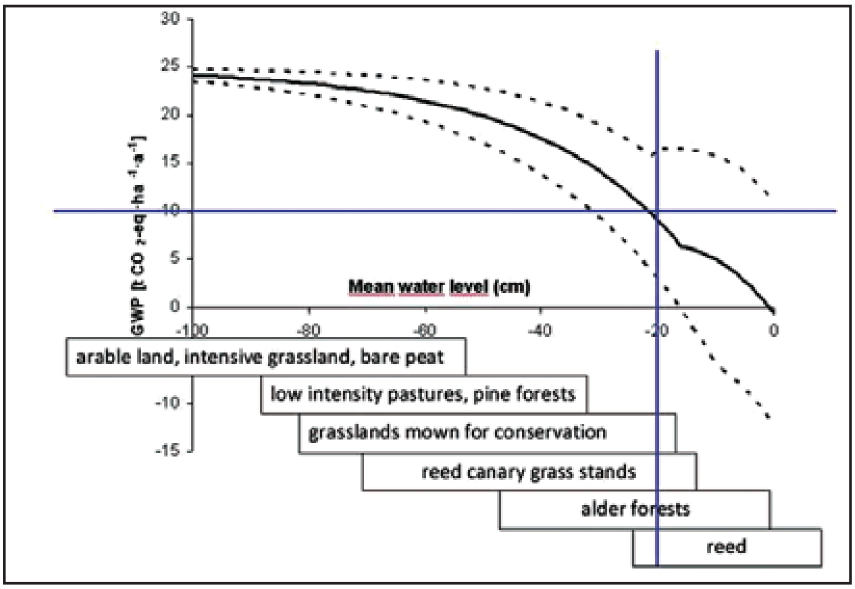

Fig. 1: Net soil emissions from temperate peatlands in relation to mean annual water level for different types of land use, expressed in Global Warming Potential (GWP) (after Couwenberg et al. 2008). N_2O emissions are conservatively neglected. The blue lines mark a reduction of 10-15 tons CO_2 eq ha^{-1} a^{-1} as compared to conventional peatland agriculture and forestry.

Climate aspects

Drainage of peatlands for conventional agriculture, forestry and peat extraction and the use of peat for energy and growing media are currently worldwide responsible for CO_2 emissions of 2 gigatons (= 2,000 megatons) per year, i.e. for 6% of the total anthropogenic CO_2 emissions (Joosten 2009).

Recent efforts to mitigate anthropogenic GHG emissions include substituting fossil fuels by biofuels, i.e. fuels produced from biomass with a short regeneration cycle. Also drained peatlands are increasingly used for the production of biomass fuels. Such cultivation (e.g. oil palm in Southeast Asia, sugar cane in Florida, maize and *miscanthus* in temperate Europe, and part of the peatland forest wood in Scandinavia) generally leads to (much) larger CO_2 emissions from the oxidizing peat soil than can be saved by replacing fossil fuels (Couwenberg 2007, Wicke et al. 2008, Sarkkola 2008).

Biogas from maize cultivated on drained peatlands, for example, leads to emissions of some 880 t CO_2 per terajoule (TJ) produced energy, palm oil from peatland to 600 t CO_2 TJ^{-1}. This is much higher than the CO_2 emissions from combustion of fossil fuels like peat (106 TJ^{-1}), coal (anthracite, 98 TJ^{-1}), oil (73 TJ^{-1}) or natural gas (52 TJ^{-1}) (IPCC 2006). Paludicultures on rewetted drained peatlands, in contrast, contribute to climate change mitigation in two ways:

- by reducing GHG emissions from drained peatland soils (Fig. 1),
- by replacing fossil resources by renewable biomass alternatives.

Young Alder (*Alnus*) plantation on rewetted fen peatland. Photo: M. Succow

Modified Seiga reed harvester for summer cutting in Rozwarowo, Poland. Photo: W. Wichtmann

An example of the positive climatic effect of paludiculture is the cultivation of common reed (*Phragmites australis*) on rewetted peatland. The rewetting as such results in a GHG emission reduction of some 15 t CO_2 eq ha^{-1} a^{-1} (Fig. 1). With a conservative yield of 12 t DM ha^{-1} and a heating value of 17.5 MJ kg DM^{-1}, the reed of one hectare can replace fossil fuels in a cogeneration plant that would otherwise emit 15 t CO_2. Assuming GHG emissions from handling (mowing, transport, storage, delivery and operation of the combustion plant) to amount to 2 t CO_2 eq ha^{-1}, using reed biomass from paludiculture would thus avoid emissions of almost 30 t CO_2 eq ha^{-1} a^{-1} (Wichmann & Wichtmann 2009).

Biodiversity aspects

Rewetting of drained peatland is generally beneficial for nature conservation as strongly degraded peatlands are biodiversity deserts. When agricultural land use and peat oxidation have enriched the soil with nutrients, rewetting often leads to high productive but species-poor vegetation. Regular harvesting of the biomass then keeps the vegetation short and the litter layer thin, reduces the trophic level and allows low competitive species to establish and hold ground. An example is the Aquatic Warbler (*Acrocephalus paludicola*), a fen mire flagship species and the only globally threatened passerine species of continental Europe. The species had its natural habitat in low productive fen mires with permanently high water levels. With increasing drainage and eutrophication, the warbler became more and more land use dependent, because only regular cutting maintains the open, sparse vegetation the species requires (Tanneberger et al. 2010).

On the other hand, biomass use may also conflict with nature conservation, e.g. when early cutting for biogas production destroys breeding habitats or when winter harvesting leaves insufficient old-grown reed. To prevent conflicts clear priorities have to be formulated.

In case of areas designated as conservation sites, paludiculture must be considered as a cost-effective management option, instrumental but ancillary to conservation.

On former strongly degraded sites, where any rewetting and management will increase biodiversity, climate benefits can prevail. Here, monitoring is recommended to detect the appearance of protected species and habitats and to be able to modify management. Care has to be taken, however, that the new biodiversity values do not frustrate paludiculture management that has caused the re-appearance of these values in the first place.

Phalaris-bales waiting for burning in the co-generation plant. Photo: W. Wichtmann

Planting reed before rewetting. Photo: W. Wichtmann

Economic implications

In the temperate zone most drained peatland was used as pasture or meadow. Nowadays large areas are abandoned because of progressive soil degradation, insufficient productivity, too low fodder quality for dairy cattle, and regional decline in livestock. Grazing for meat production, e.g. by suckler cows or lambs, generates deficits of several hundred Euro per hectare per year and fully depends on agricultural subsidies (Plachter & Hampicke 2010). The continued costs of drainage - with all external diseconomies - are, furthermore, largely borne by society, not by the individual user.

Paludicultures offer an alternative agricultural future for degraded peatlands. Although special wetland-adapted harvest machinery is required, thermal utilisation of winter harvested *Phragmites* reeds in Northeast-Germany can fully compete with *Miscanthus* or straw from mineral soils also without subsidies or payments for ecological services. For individual farms, the perspectives of paludiculture are decisively determined by the agricultural subsidies that competitive (but unsustainable!) land use options receive (e.g. EU direct payments), not by objective economic costs and revenues (Wichmann & Wichtmann 2009).

Paludicultures provide valuable ecosystem services that are not (yet) paid, including reduction of GHG emissions, protection of ground- and surface water, retention of water in the landscape and conservation of biodiversity. From a macroeconomic point of view, transfer payments to farms that put paludiculture into practise are therefore a very cost-effective way to fulfil international commitments with respect to protecting climate, water and biodiversity.

Conclusions

Paludiculture is agricultural production on rewetted peatland that does not degrade the peat layer and even adds to peat accumulation.

Paludiculture
- decreases GHG emissions from the peat soil,
- allows the production of “clean” biomass that hardly competes with food production, and
- restores and maintains habitats for rare and threatened species.

The use of biomass fuels from drained peat soils perversely results in higher emissions than using fossil fuels. Drained peatlands should therefore not be stocked with biomass energy crops, but rewetted and used for paludiculture.

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