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TOWARDS MORE DIVERSITY IN PALUDICULTURE – A LITERATURE REVIEW OF USEFUL WETLAND PLANTS

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SUMMARY

Peatlands have been drained and reclaimed for agriculture and forestry in many parts of the world with increasing negative impact on environment and sustainability of production. Paludiculture, the wet cultivation of peatlands, offers a sustainable agricultural alternative that conserves the peat soil and minimizes negative environmental impacts. The cultivation of *Phragmites australis* as a bioenergy crop or building material illustrates the practicality and economic feasibility of paludiculture (Wichtmann and Schäfer, 2007). Paludiculture furthermore contributes to the conservation of rare species and habitats and to a reduction of greenhouse gas emissions. Next to the few established crops, a wealth of potential crops exists that offer a plethora of possibilities for paludiculture. This paper introduces the 'Database of Potential Paludiculture Plants', the DPPP, illustrating the diversity of useful wetland plants in Europe. The utilisation options of these potential crops vary from medical to energy and food crops for humans and animals.

KEYWORDS: paludiculture, wetland plants, biodiversity, peatland utilisation, rewetting

INTRODUCTION

Conventional land use on peatlands typically involves drainage. Drainage leads to the loss of the natural ecosystem services provided by peatlands (Wichmann et al., this volume), including loss of biodiversity (Minayeva, 2008). Moreover, oxidation of the aerated peat results in the release of large amounts of greenhouse gases to the atmosphere and of nitrate to adjacent surface waters. A drained peatland loses – depending on the climate – some millimeters up to several centimeters of peat per year. The resulting lowering of the peatland surface necessitates a continuous deepening of the drainage ditches, which again enhances peat oxidation, surface lowering, ditch deepening, etc…, a phenomenon known as the vicious circle of peatland utilisation (Joosten and Clarke, 2002). All exploitation of peatlands that involves drainage leads to loss of productive soil and is a dead end street. New techniques have to be developed that combine productive use with the maintenance of the peat soil and in addition support the natural ecosystem services of wet peatlands.

Paludiculture (Latin '*palus*' = swamp), the cultivation of biomass on wet and rewetted peatlands, is an innovative alternative to conventional peatland agri- and silviculture. The precondition for paludiculture is that the peatland is sufficiently wet, so that the peat soil is conserved or new peat may even accumulate. The quintessence of paludiculture is to cultivate plants that thrive under wet conditions and produce biomass of sufficient quantity and quality without negatively affecting the peat soil (Wichtmann and Joosten, 2007). Paludiculture on rewetted peatlands has the potential (Tanneberger and Wichtmann, 2011):

- To reduce greenhouse gas emissions
- To restore the sink function for carbon and nitrogen
- To establish productive, site adapted (sustainable) land use
- To restore habitats for rare and threatened species
- To revitalise traditional types of land use in combination with new ways of processing
- To produce biomass with versatile utilisation options (cf. tab.1)

In recent decades, paludicultures have been tested in several pilot projects on rewetted peatlands. The cultivation of Common Reed *Phragmites australis* as a bioenergy crop or as a raw material nicely illustrates the practical and economic feasibility of paludiculture (Wichtmann and Schäfer, 2007). Technical solutions for harvesting of naturally developed or artificially established stands are available. Traditional use of *Phragmites* for roof thatching is well established. The use for bioenergy has been tested in form of bales, pellets and as biogas (Wichmann and Wichtmann, 2009). Different other types of use exist or are being developed, like insulation mats, fiber-based damming material and various applications of cellulose (Tanneberger & Wichtmann, 2011). Next to Common Reed, Cattail harvest (Wild *et al*., 2001, Grosshans et al. 2011 , Dubbe *et al*.. 1988), Black Alder cultivation (Schäfer and Joosten, 2005) and Sphagnum farming (Gaudig *et al.,* this volume; Wichmann et al., this volume) have been tested with promising results. The above examples have fostered the search for more paludiculture crops. Wetland plants can be utilised in a plethora of products and applications (cf. tab. 1 & 2). To help identify potential crops we compiled a “Database of Potential Paludiculture Plants”, the DPPP, that shows the high diversity of useful wetland plants and utilisation options for biomass from wet peatlands. Here we report on findings for potential paludiculture plants in Europe, which is the region with the largest proportion of degraded peatlands and thus with the highest potential for paludiculture worldwide (Barthelmes *et al.*, this volume).

MATERIAL & METHODS

Common crops (economic plants) adapted to waterlogged conditions were selected to identify the most important useful wetland plants. Secondly, typical peatland plants (Julve 1998 ff) were scrutinized for potential forms of use to complete the list. The DPPP collates information on:

- plant characteristics & morphology

- their distribution & natural habitats
- modes of their cultivation & propagation
- their utilisation options

Wetland plants have versatile utilisation options. We identified seven utilisation categories (tab.1).

Table 1. Description of the utilisation categories.

Utilisation category	**Species provide products that (directly & indirectly):**
Human food	feed people (nourish and enjoy)
Medicine & poison	influence people’s physical constitution (medicine, drugs, poisons)
Animal fodder	feed animals
Ornamental	influence people’s mental constitution (flowers, odeurs, cosmetics)
Agricultural conditioner	support plant crops (agri-, sylvi-, horticulture) and husbandry (growing media, fertilizers, herbi- & pesticides, enzymes)
Energy	provides warmth and force (wood, cellulose, biomass)
Raw material	are useful non food or non energy materials (construction, chemical or insulation materials)

Our main initial focus was on the Holarctis, because here the highest potential for paludiculture in terms of area is found (Barthelmes et al., this volume). Moreover, the Holarctis is very well studied with much literature of good quality, describing plants and their ecology and habitat demands. Available internet resources like efloras.org, ars-grin.gov, mansfeld.ipk-gatersleben, plants.usda.gov, pfaf.org, sped up filling in of the database. For practical purposes, some species are united into groups, within which characteristics and utilisation options are similar and transferable, e.g. *Sphagnum* spp., *Carex* spp. or *Salix* spp..

RESULTS & DISCUSSION

Until now, we identified 560 potential paludiculture plants, of which 196 are native to Europe. Of these 196 taxa, 120 are forb/herb species, 40 graminoid species, 25 shrub species, 10 tree species and 1 moss genus. Table 2 presents a selection of taxa for the different utilisation categories.

Among the 196 useful wetland plants of Europe there are several rare species, for instance *Menyanthes trifoliata* or *Calla palustris*. The biggest threat to wetland plants in Europe is direct habitat loss (Bilz *et al.*, 2011). Paludiculture could contribute to restoring threatened habitats and supporting the conservation of rare species. Threatened *Drosera* species have, for example, established as a ‘weed’ on Sphagnum cultivation areas. Some surveyed taxa are facultative wetland species that are already in conventional cultivation under dry conditions. Recent studies illustrate the feasibility of wet cultivation and specialised techniques can be developed if necessary. Not every beneficial wetland plant is suitable for paludiculture. A primary concern of paludiculture is the conservation of the peat soil. Paludiculture thus intends to use that part of net primary production that is not necessary for peat formation. In temperate zones, where plant productivity is high, peat is generally formed by roots and rhizomes. Hence products derived from below ground parts of plants cannot be provided through paludiculture. An additional aspect of plant suitability concerns economic and technical feasibility.

Table 2. A selection of useful wetland plants, ordered by main utilisation category. Within the category primarily used plant parts, “roots” includes rhizomes, tubers and other belowground plant parts; ‘plant’ referred to the entire living or dead plant. The reference list can be found in the ‘Database of useful wetland

Scientific name	**Main use categories**	**Family**	**Vernacular name**	**Life form**	**Primarily used plant parts**
Angelica archangelica L.	medicine, food	Apiaceae	angelica	forb/herb	roots, leaves
Drosera rotundifolia L.	medicine, ornamental	Droseraceae	sundew	forb/herb	leaves, stems
Frangula alnus Mill.	medicine, raw material, ornamental	Rhamnaceae	alder buckthorn	shrub	bark, wood, plant
Mentha aquatica L.	medicine, food	Lamiaceae	water minth	forb/herb	leaves
Menyanthes trifoliata L.	medicine	Menyanthaceae	bog-bean, buckbean	forb/herb	leaves, stems
Myrica gale L.	medicine, food	Myricaceae	bog myrtle, sweet gale	shrub	leaves, fruits
Petasites hybridus (L.)P.Gaertn.,C.A.Mey.&Scherb.	medicine	Asteraceae	butterbur, bog rhubarb	forb/herb	leaves, roots
Symphytum officinale L.	medicine, food	Boraginaceae	comfrey	forb/herb	roots, leaves
Valeriana officinalis L.	medicine, ornamental	Valerianaceae	valerian	forb/herb	roots, plant
Apium graveolens L.	food, medicine	Apiaceae	wild celery	forb/herb	leaves, stems, seeds
Cyperus esculentus L.	food	Cyperaceae	chufa, yellow nutsedge, tiger nut	graminoid	roots
Hierochloe odorata (L.)P.Beauv.	food, medicine, raw material	Poaceae	sweet grass, bison grass, manna grass	graminoid	stem, leaves, aboveground biomass
Oxycoccus palustris Pers.	food	Ericaceae	cranberry	forb/herb	fruits
Rubus chamaemorus L.	food	Rosaceae	cloudberry	shrub	fruits
Trapa natans L.	food	Lythraceae	water caltrop, water chestnut	forb/herb	seeds
Agrostis gigantea Roth.	fodder	Poaceae	red top, bentgrass	graminoid	aboveground biomass
Glyceria maxima (C. Hartm.) Holmb.	fodder, energy	Poaceae	reed sweet grass, giant manna grass	graminoid	aboveground biomass
Phalaris arundinacea L.	fodder, energy	Poaceae	reed canary grass	graminoid	aboveground biomass
Arundo donax L.	energy	Poaceae	giant cane, spanish cane, arundo	graminoid	aboveground biomass
Carex spp. L.	energy, raw material, food	Cyperaceae	sedge	graminoid	aboveground biomass
Cladium mariscus (L.)Pohl.	energy, raw material	Cyperaceae	saw-sedge, swamp sawgrass	graminoid	aboveground biomass
Phragmites australis (Cav.) Trin. ex Steud.	energy, raw material	Poaceae	common reed	graminoid	aboveground biomass
Salix spp. L.	energy, raw material	Salicaceae	willow, sallow, osier	shrub or tree	aboveground biomass, stems
Alnus glutinosa (L.)Gaertn.	raw material, energy	Betulaceae	black alder	tree	aboveground biomass, wood
Eriophorum vaginatum L.	raw material, ornamental	Cyperaceae	cotton grass	graminoid	plant, stems, flowers
Juncus acutus L.	raw material, ornamental	Juncaceae	spiny rush, sharp rush, koga	graminoid	stems, flowers
Pinus sylvestris L.	raw material, energy, ornamental	Pinaceae	scot's pine	tree	wood
Schoenoplectus tabernaemontani (C.C.Gmel.) Palla	raw material, energy	Cyperaceae	soft stem bulrush, river club rush	graminoid	stems, aboveground biomass
Typha spp. L.	raw material, energy, agricultural conditioner	Typhaceae	cattail	graminoid	aboveground biomass, seeds
Sphagnum spp. L.	agricultural conditioner, raw material	Sphagnaceae	peat moss	moss	living biomass
Calla palustris L.	ornamental, food, medicine	Araceae	water arum, calla	forb/herb	plant, roots

Dactylorhiza maculata (L.) Soó	ornamental, food, medicine	Orchidaceae	spotted orchid	forb/herb	plant, roots
Trollius europaeus L.	ornamental, medicine	Ranunculaceae	globeflower	forb/herb	plant, roots

Growing demand for sustainable land use options will stimulate innovations in these fields. Most paludicultures are still in their infancy. Further research is required into optimization of cultivation techniques, selection and propagation of suitable eco-types, development of site adapted machinery, and long-term environmental effects (peat hydraulics, peat formation, emissions, biodiversity; cf. Wichmann et al., this volume).
The DPPP will be made available on the internet as a decision making support tool for the further establishment of paludicultures.

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