WEIHENSTEPHAN · TRIESDORF
University of Applied Sciences

Johann Krimmer
Dipl. Ing. FH
Samen und Pflanzen
für naturnahes Grün

Peatland Science Centre

T. EICKENSCHEIDT, J. KRIMMER, M. DRÖSLER

GUIDELINE FOR THE ESTABLISHMENT OF FEN PALUDICULTURES

Bayerisches Staatsministerium für Umwelt und Verbraucherschutz

Europäische Union
Europäischer Fonds für regionale Entwicklung

Guideline for the establishment of fen paludicultures

T. Eickenscheidt[1], J. Krimmer[2], M. Drösler[1]

[1] Tim Eickenscheidt, Matthias Drösler, Hochschule Weihenstephan-Triesdorf, Institut für Ökologie und Landschaft, Peatland Science Centre, Am Hofgarten 1, 85354 Freising.
[2] Johann Krimmer, Samen und Pflanzen für naturnahes Grün, Sünzhauser Str. 5, 85354 Freising-Pulling.

The guideline for the establishment of fen paludicultures summarizes the results of the project MOORuse - Paludiculture for fen peatlands in Bavaria - Establishment, Climate Relevance & Environmental Effects, Utilization Potentials and Economic Viability (FKZ 64 b -U8639.1-2015/8-14; Duration 03.2016 - 31.12.2022). For a detailed description, please refer to the final report of the MOORuse project (https://forschung.hswt.de/publikationen).

The project MOORuse was funded by the Bavarian State Ministry for the Environment and Consumer Protection (StMUV) and the European Union within the framework of the EU program IWB EFRE. The responsibility for the content of this publication lies with the authors.

Acknowledgements

Our special thanks goes to the farmers Mr. Ludwig Büchler, Mr. Jochen Krauss and Mr. Josef Ziegeltrum for providing the study areas and for their active support in all technical project matters. Further, we thank the Arbeitsgemeinschaft Schwäbisches Donaumoos e.V. and the Donaumoos-Zweckverband, especially Anja Schuhmann, Ulrich Mäck and Michael Hafner for the land acquisition, the implementation of the rewetting measures as well as for the land management.

Peatland Science Centre

IMPRESSUM

- Guideline for the establishment of fen paludicultures
-
- Year of publication: 2023

EDITOR

- Prof. Dr. Matthias Drösler
- Professorship for Vegetation Ecology
- Research professorship for climate change and peatland ecosystems

ADDRESS

- Peatland Science Centre
- Hochschule Weihenstephan-Triesdorf
- Am Hofgarten 1 | 85354 Freising
- www.hswt.de

EDITING, DESIGN AND TYPESETTING

- Tim Eickenscheidt | Carla Bockermann
- Peatland Science Centre
- Hochschule Weihenstephan-Triesdorf
- E-Mail: tim.eickenscheidt@hswt.de

LAYOUT

- Tim Eickenscheidt | Carla Bockermann | Ella Papp

IMAGE REFERENCE

- Cover, Fig. Nr.: 1, 2, 3 (left picture), 5, 6 (left picture & center picture), 7 (right picture) ©Tim Eickenscheidt
- Fig. Nr.: 3 (right picture) © Anja Schumann
- Fig. Nr.: 4 (right picture), 6 (right picture), 7 (left picture) © Felix Lipp
- Fig. Nr.: 4 (left picture) © Belinda Strahl

TABLE OF CONTENTS

1 PREFACE

In the last decades, drainage and intensive agricultural use of organic soils has caused peatlands to lose their ecological service functions and become "hot-spots" for greenhouse gas emissions. Currently, agricultural and forestry use of drained peatlands contributes 7.5% to total national emissions in Germany *(*UBA, 2021). If carbon dioxide (CO_2) and methane (CH_4) emissions from agricultural use of drained organic soils are additionally added to the direct nitrous oxide (N_2O) emissions[1], 45% of total emissions from the agricultural sector come from intensive peatland use (Tiemeyer et al., 2020). Several research projects have shown that the rewetting and restoration of degraded peatlands is the only efficient measure to achieve permanent climate protection and promote the diversity of endangered species (e.g. Drösler, 2005; Beetz et al., 2013; Tiemeyer et al., 2013). In contrast to restoration of peatlands, paludiculture (derived from the Latin word "palus" for swamp or morass) offers peatland-friendly, site-adapted alternatives, which can be combined with partial or complete rewetting.

Focal areas for the establishment of paludiculture should be previously intensively used arable or grassland sites on drained organic soils. Both land use types have the highest emission factors of 40.4 and 31.7 t CO_2-eq. ha^{-1} yr^{-1} (Tiemeyer et al., 2020), respectively, and thus offer the greatest potential for significant greenhouse gas (GHG) reductions in the agricultural sector. Based on current knowledge from the MOORuse project, paludiculture emits approximately −13.0 ± 13.9 t CO_2-eq. ha^{-1} yr^{-1} at a mean annual groundwater level in the range of +4 to −10 cm relative to the ground surface. Thus, paludiculture can act as a significant CO_2 sink. At the same time, the different paludiculture plants offer the possibility of material or energetic utilization. This can substitute other fossil energy sources, leading to a further reduction of GHG emissions.

In order to make paludiculture an economically attractive option for farmers in the future, on the one hand government funding programs, such as the Bavarian peatland farming program, are in preparation. On the other hand, utilization-processing pathways have to be developed, for which investment support for production facilities will be necessary. The continuous new and further development of high-quality products from paludiculture biomass, as well as processing on an industrial scale, will lead to providing competitive contribution margins for the farm, at least for single paludiculture crop species.

In the last decade, numerous research projects focusing on paludiculture have been carried out in Germany, the Netherlands and Denmark. Despite considerable efforts, new agricultural production methods cannot be developed comprehensively over such a short time horizon. There are still considerable deficits in the subject of establishment

[1] CO_2 and CH_4 emissions from the use of drained organic soils are attributed to the land use, land use change and forestry (LULUCF) sector. Direct N_2O emissions are attributed to the agriculture sector.

procedures, long-term yield development, species variety and provenance tests, and questions of environmentally friendly fertilization. Here, it would be desirable if the relevant institutions in particular (universities, state and federal institutes) would set up large-scale trials. The present guideline is based on the investigations from the MOORuse project, which was carried out in the period 2016 to 2022 under the leadership of the University of Applied Sciences Weihenstephan-Triesdorf, Germany, with various external project partners. According to current knowledge, these are so far the most long-term and most methodologically sound experiments for the establishment and yield development of a wide variety of paludiculture plants. Despite careful and conscientious editing, this guideline can only provide an initial framework for the establishment of paludiculture. We derive recommendations for action from the numerous conducted experiments and gained experiences, which may need to be adapted to site-specific conditions.

2 CHARACTERIZATION OF PALUDICULTURE PLANT SPECIES

For paludiculture, wetland specific plants are used, which were involved in the formation of the peat body and adapted to high water levels. On rewetted degraded fens common reed (*Phragmites australis*), reed canary grass (*Phalaris arundinacea*), cattail species (*Typha* spp.), and tall sedges (*Carex* spp.) are particularly suitable plants for paludiculture. All of the paludiculture species listed are characterized by very high yields. However, common reed stands show a very slow juvenile growth, so that reasonable yields are not reached until the fifth or sixth year of growth. Afterwards, dry matter (DM) yields of up to 23.8 t ha^{-1} yr^{-1} are possible depending on the site conditions (Birr et al., 2021). Already in the third year after establishment, cattails reach yields of up to 8.8 t DM ha^{-1} yr^{-1} after seeding or planting, and maximum yields of up to 22.1 t DM ha^{-1} yr^{-1} are reported for cattail species (Birr et al., 2021). However, these high yields are presumably achieved only under permanent waterlogging conditions and the discharge of nutrient-polluted surface waters. Based on current knowledge, the climate change mitigation potential of paludiculture described in the preface cannot be achieved under such permanent waterlogging conditions due to very high methane emissions. Sedges and reed canary grass also achieve yields of up to 11.6 t DM ha^{-1} yr^{-1} by the third year of establishment. The highest biomass yields are achieved by the above-mentioned plants when complete rewetting is achieved with mean annual groundwater levels of at least −10 cm below the ground surface. Reed canary grass and the tall sedges *Carex acutiformis* and *Carex actua*, however, are relatively tolerant toward longer drought periods with groundwater levels as low as −30 cm. Reed and cattail species, on the other hand, require permanently high groundwater levels to form dense stands.

In the following, the establishment of the above mentioned plant species will be described in more detail, as they have been studied most extensively so far. In the future, the number of promising paludiculture species will probably increase, as a large number of wetland-adapted species exist worldwide. The Greifswald Mire Centre maintains a database of potential paludiculture plants for this purpose (https://www.greifswaldmoor.de/dppp.html, Abel et al., 2013).

Fig. 1 Potential paludiculture plants. a) Broad-leaved cattail (*Typha latifolia*), b) Narrow-leaved cattail (*Typha angustifolia*), c) Common reed (*Phragmites australis*), d) Reed canary grass (*Phalaris arundinacea*), e) Lesser pond-sedge (*Carex acutiformis*), f) Slender tufted-sedge (*Carex acuta*).

.

3 SITE PREPERATION

Possible rewetting methods and the necessary approval process are not the subject of this guide, but must be clarified in advance and initiated accordingly. All structural measures necessary for the rewetting of the site must be finished in the year before the paludiculture establishment. This is the only way to ensure that rapid rewetting is achieved after seeding or planting. Any drainage cutting or construction of new irrigation ditches should be scheduled to occur immediately after the main crop has been harvested in late summer (for example, in the case of cereal crops) and before the basic tillage is carried out. In order to achieve a fast, extensive rewetting after planting or sowing, it has proven useful to create shallow transverse and longitudinal ditches from the receiving water or the irrigation ditches on the site immediately after planting or sowing with a single-share plow. If this step is planned, the planting rows in these areas can remain unplanted.

4 BASIC TILLAGE

On **arable land** that is to be cultivated as paludiculture in the future, conventional tillage with a plow should be carried out in autumn. The plowing depth should be 20-25 cm. Since the trafficability of the areas in autumn is often even more favorable than in spring, it is recommended to post-process the area after plowing via a rotary cultivator with a roller. This step also serves to reconsolidate the soil. Since arable sites are generally easier to drive on throughout the year compared to grassland sites on fen peatlands, the basic tillage and seedbed preparation can be planned more flexibly in terms of timing. To keep methane emissions as low as possible after rewetting in the following year, the amount of biomass incorporated should be as low as possible (as in the case of e.g. silage maize or cereals followed by straw collection). The seeding of a catch crop should not be done. On erosion-prone sites, plowing can also be done in the spring depending on the trafficability. In general, care should be taken to avoid too many tillage steps before sowing, as the topsoil of degraded fen soils quickly loses its structural stability. In addition, many topsoils already have a "strongly moorshyfied (nHm)" degradation status. In the desiccated state these soils are very vulnerable to erosion by water and wind, and can only absorb water very poorly (hydrophobic surfaces).

According to the current legal situation, paludicultures are classified as permanent crops under the agricultural subsidies of the EU Common Agricultural Policy. Therefore, the cultivation of paludiculture on **permanent grassland** is considered as grassland conversion to cropland and may require approval. Certain grassland areas with special conservation status e.g. habitat protection areas, Natura2000 habitats, or nature conservation areas must be preserved and are excluded from conversion. Thus, for sensitive permanent grassland areas (GAEC 9) as well as for permanent grassland on peatlands (GAEC 2), there is a complete prohibition of conversion and ploughing in terms of agricultural subsidy law. An approval for the conversion of permanent grassland is only possible if certain requirements are met (see e.g. StMELF, 2023). In the case of the establishment of paludiculture, numerous of these requirements are fulfilled from a scientific point of view. Accordingly, an exception to the conditionality GAEC 2 should be made.

With respect to current knowledge, it is inevitable for the establishment of paludicultures that the old grass sward is completely removed. Therefore, the final cut in autumn should be done as low as possible so that less above-ground biomass remains. Alternatively, the area can be mulched after the last cut. Thereby the following applies: The less fresh biomass that remains, the lower the methane emissions will be immediately after the water level is raised in the following year. Eliminating the old sward with herbicides should be avoided. To avoid an incomplete incorporation of the biomass and old sward in the seed-bed, conventional tillage with a plow (or plow-packer combination) that is additionally equipped with a skimmer and disc coulter is recommended. The plowing depth should also be 20-25 cm, analogous to the arable site. For reconsolidation, a further soil cultivation step with a rotary cultivator with a roller is recommended after plowing. As an alternative to plowing, a reverse rotary tiller with a tilling depth of 10-13 cm can also be used. Plowing or rotavating should be done as late as possible in the year, but is based on the trafficability of the area. According to current knowledge, direct drilling without destroying the old sward is not recommended.

5 SOWING

Sowing of common reed and cattail can be recommended if immediately (1-7 days) after sowing the groundwater level can be raised close to the ground surface. Flooding of the area must be avoided. This depends primarily on site conditions, the amount of available water, and the rewetting procedure. The sowing of reed canary grass is recommended without restrictions. However, a prompt partial rewetting or complete rewetting is also necessary for reed canary grass to favor the competitive strength against emerging weeds. All sowing experiments with sedges (*Carex* spp.) failed or were insufficient in the field experiments of the MOORuse project. Currently, the project "Peatland compatible management measures" (MOORbewi) at the University of Applied Sciences Weihenstephan-Triesdorf and the Bavarian State Institute for Agriculture (Lfl) is conducting further experiments on this topic. According to current knowledge, sowing of sedges cannot be recommended. A final assessment on the sowing of sedges will be possible after the completion of the MOORbewi project (2024).

5.1 SEED-BED PREPERATION

Careful and proper sowing is of crucial importance to the establishment success of paludicultures. After the basic tillage, a "false seedbed" can be created via rolling (e.g. grassland roller) two to three weeks before the sowing date. This depends on the expected weed pressure and trafficability of the area. The soil temperature should already be above 10 °C. Herbicides should not be used to control the emerging weeds, as these remain persistent in the peat body for a very long time. Instead, depending on the stage of development of the weeds, shallow 1-2 cm deep mechanical tillage with a tine harrow (up to the cotyledon stage) or, if the cotyledon stage has been exceeded, 4-5 cm deep tillage with a rotary harrow (Fig. 2) should be carried out. Since most paludiculture plants have very small seeds (Table 1), a fine settled seedbed is not sufficient. It is recommended to compact the soil with a grassland roller once or twice immediately before seeding (Fig. 2). Thereby, rolling serves to create a flat seed horizon, which allows the very shallow sowing depth to be set more reliably (Table 1). Further, the rolling also helps to restore soil capillarity that leads to a better water supply for the germinating seed.

Fig. 2 Left picture: A fine seedbed is created with a rotary harrow. Right picture: Immediately before planting or sowing, the seedbed is compacted with a grassland roller.

5.2 SEEDING TECHNIQUE

In order to better handle the very small seed quantities for paludiculture plants, it has proven useful to mix the seed with soymeal to increase the volume. Care must be taken to ensure that the soymeal has the same grain size as the seed. In addition, it is essential to ensure homogeneous mixing of seed and soymeal. To determine the exact sowing rate, a calibration test must be carried out before sowing. Universal drill seeder with a row spacing of 12-14 cm are suitable for seeding reed canary grass, cattail and reed. Depending on the design of the drill seeder, the seed of cattail and reed must be increased with soymeal accordingly to the minimum adjustable seed quantity of the machine.

In the "Paludi-PRIMA" project of the Greifswald Mire Centre, first experiments were conducted on sowing cattail using a drone on previously rewetted areas. Due to the very low seeding rate (Table 1), this can be a very cost-effective alternative to conventional seeding. In addition, the initiated successful rewetting prior to seeding can reduce the risk of seed failure to germinate or seed death. This is especially recommended in areas where it is expected that sufficient rewetting cannot be achieved in the near-time.

Fig. 3 Left picture: Self-made five-row seed drill machine (manufactured by LfL Landtechnik) for seed rates of < 2 kg ha^{-1}. Right picture: Universal drill seeder during the seeding of reed canary grass at the study site Riedhausen.

5.3 SEEDING DATE

For all described paludiculture species, sowing should be done preferably in the period from mid-April to the end of May. The later the sowing takes place, the higher the risk that the seeds or seedlings die due to the high temperatures that the black peat reaches under sunlight. This risk is significantly reduced by quickly initiating rewetting after sowing. Attempts to protect the seeding against high temperatures by means of a thin layer of straw have not yet been practiced, but could be promising under certain circumstances. Reed canary grass sowing can be extended to the end of July. Sowing paludiculture from August onwards is not recommended, since the risk increases that the roots of the young plants will break off in frost or that the plants will freeze out of the ground and dry out.

5.4 SEED QUANTITY AND SEED MATERIAL

Table 1 provides an overview of the recommended seeding rates. Apart from reed canary grass, there is still a shortage of purchasable seed for all the paludiculture crops listed. The extent to which paludiculture can be implemented on a large scale in the future depends largely on whether sufficient seed is produced. From a nature conservation point of view, it must also be clarified to what extent the focus should be on autochthonous seed. Studies on the germination capacity and yield development of different varieties and provenance are few to none so far. Within the project "Paludi-PRIMA" of the University of Greifswald, first genotypings of reed have been carried out and reed stands in Mecklenburg-Western Pomerania have been characterized. Seed collection experiments in the MOORuse project indicate that sedge stands do not form germinable seed annually.

Table 1 Recommended seeding rates for paludiculture

Plant species	Seeding rate [kg ha^{-1}]	Sowing depth [cm]	Thousand grain weight [g]
Reed canary grass	10 - 15	1 - 2	1.14286
Common reed	0.5 - 1	0 - 0.5	0.1087
Cattail	0.5 - 1	0 - 0.5	0.0339 - 0.04082

6 PLANTING

Planting of pre-grown root ball plants can be recommended for all paludiculture without any restrictions. According to current knowledge, planting is so far the only possibility to establish sedges (*Carex* spp.) satisfactory. For the other paludiculture plant species investigated, seeding is an option (see above). Establishment of paludicultures by planting is always associated with very high costs and a higher effort of organization in advance. On the one hand, horticultural enterprises have to be commissioned with the cultivation of large numbers of balled plants. On the other hand, greater logistical challenges arise for the transport and temporary storage of the required plants. The planting itself also requires appropriate technology as well as trained staff, which is usually only available to the farm through contracting companies. Planting can be used wherever rewetting may not be achieved as quickly as needed for sowing. However, very close attention must be paid here to the weather conditions in order to guarantee that the plants do not dry out! The presence of crows and storks after planting has turned out to be a problem in the MOORuse project at the experimental site in Langenmosen. The animals tend to pull the plants out of the ground during drought and search for worms under the root balls. This can destroy entire crops of several thousand plants in a very short time. It has proved to be extremely difficult to deter the animals. As a safe alternative, the crops could be protected with cultivation nets. However, the use of these nets is only feasible to a very limited extent for large-scale establishment (Fig. 7).

6.1 PLANT-BED PREPERATION

The plant-bed preparation is to be carried out analogously to the seed-bed preparation (Section 5.1).

6.2 PLANTING TECHNIQUE

For the establishment of large areas by means of planting, only mechanical planting techniques can be considered to ensure a sufficient area capacity. Due to the low soil resistance, the use of conventional vegetable planting machines cannot be recommended so far (Fig. 4). Further experiments with different currently available attached implements or self-propelled machines are urgently needed here. Very good results could be achieved with a cultivation planting platform with a leading planting hole roller (self-made by Johann Krimmer, Samen und Pflanzen für naturnahes Grün). The leading roller makes it possible to set different rows and planting distances. The planting capacity with this system is about 4000 plants per hour with a well-rehearsed planting team (Fig. 4).

Fig. 4 Left picture: Mechanical planting of *Carex acutiformis* at the study site Riedhausen. The planting holes are pressed into the soil at the defined row and planting distance via the leading roller. Here, five rows with a distance of 0.5 m are planted in parallel. The planting capacity is approx. 4000 plants per hour. Right picture: Mechanical planting of *Carex acutiformis* at the study site Langenmosen using a semi-automatic vegetable seedling transplanter. Despite rolling the area twice, the soil resistance was too low for this machine, which led to clogging of the coulters and disks.

Fig. 5 Left picture: Planting experiments with different plant spacing at the study site in Freisinger Moos. Right picture: Seeding experiments with a row spacing of 0.5 m with reed. A dense weed flora had developed between the rows, which could no longer be controlled mechanically after rewetting. However, due to the high competitive strength of reed under very wet conditions, this did not pose a threat for the subsequent crop years.

6.3 PLANTING DATE

For all described paludiculture species, planting should be done in the period from the end of May to the end of July. Early planting requires that the seedlings must be grown the year before and overwintered in the greenhouse. As a result, they are usually much more expensive to purchase. Planting paludiculture from September onwards is not recommended, as there is a risk (at least in southern Germany) that the root balls will freeze out of the ground and the plants will dry out.

In the week prior to delivery, a liquid multinutrient fertilization of the balled plants at the horticultural enterprise is recommended. For sedges and reed canary grass, the above-ground biomass should be cut to one-third before planting to reduce transpiration. Before planting, the root balls of the plants should be water saturated in the growing plates. Thus, depending on the weather, the first critical phase can be bridged until complete rewetting of the field or the onset of rain. In advance, it should be clarified to what extent technology is available for emergency irrigation in case rewetting does not take place quickly enough or it fails to rain. Slurry spreaders with side-discharge have proven to be useful for this purpose as they have an acceptable area capacity (Fig. 7).

Fig. 6 Left picture: Daily control of greenhouse temperature and soil moisture is essential for successful paludiculture seedling cultivation. Middle image: Sturdy seedlings of *Typha angustifolia* ready for planting in the field. Right picture: Immediately before planting, the root balls should be saturated with water.

6.4 PLANT SPACING AND PLANT SIZE

Table 2 lists the recommended different plant spacing. In the literature, plant spacings for reed and cattail are often wider. This however depends on the size and quality of the seedlings, expected weed pressure, and nutrient availability. The given plant spacing applies to seedlings that have been cultivated in 77 grows plates (QuickPot Standard QP® 77). This size provides a good shoot to root biomass ratio. Thereby, the root ball is squared with the dimensions of 4 x 4 cm and a height of 5 cm.

Sedges, cattails and reed have a very pronounced vegetative growth via rhizomes. Therefore, a rapid growth between the planting rows can be achieved under rewetted conditions. Under favourable site conditions, all paludicultures show a very high competitive capacity and monodominant stands are usually formed already in the second or third growth year. With the given plant spacing, full yield for cattails and sedges is achieved as early as in the second year of establishment. Reed, on the other hand, has a very slow juvenile development and the full yield capacity is not reached until the fifth or sixth growth year. Narrower plant spacing than recommended does not significantly increase the yield performance of reed.

Table 2 Recommended plant spacing for paludiculture plants

Plant species	Recommended plant spacing	Plant size
Sedges	0.50 m x 0.32 m	Growing Plate QuickPot Standard QP® 77
Common reed	1.00 m x 0.32 m	Growing Plate QuickPot Standard QP® 77
Cattail	1.00 m x 0.32 m	Growing Plate QuickPot Standard QP® 77

Fig. 7 Left picture: If rewetting does not occur fast enough due to drought, it may be necessary to irrigate the seedlings within 2 days after establishment to prevent complete failure of the planting. Right picture: To protect the planted seedlings against being pulled out by crows or storks, it may be necessary to secure them with a cultivation net. However, this is only possible for a limited size of the area.

7 PLANT CARE – PLANT PROTECTION

Long-term studies on the care of paludicultures do not yet exist. The use of herbicides is prohibited on rewetted paludicultures according to the legal regulations (Plant Protection Act, various regulations). Due to the very high competitive capacity of paludiculture plants, monodominant stands are almost always formed under optimal growing conditions. The maintainance of paludiculture is mainly controlled by the ground water level hight and secondly by the mowing frequency. Weeds develop primarily when the water level drops below −10 cm relative to the ground surface or fluctuates greatly over the course of the year. For the cattail species, reed, and sedges, periods of flooding in spring and early summer can promote their competitive strenght. Reed canary grass, on the other hand, reacted with yield reductions under persistent flooding periods in springtime. Depending on the site conditions and weed pressure in one-cut reed canary grass and sedge stands (one winter mowing), it may be advantageous to mow them twice a year at intervals of three to four years. The first cut should not be carried out before the beginning of July.

If the rewetting does not succeed as fast as expected after planting or seeding, or if the water level drops due to drought after the plants have successfully developed, it may be advantageous to mulch (10 - 15 cm height) sedges or reed canary grass to suppress emerged weeds and annual grasses. For both cattail species and reed, mulching is not recommended at this stage as they are very sensitive to being cut at a juvenile age and there is a risk of complete failure. Depending on the water level, an adapted meadow care (rolling, dragging) may be recommended for reed canary grass and the sedges in spring (Flyer Rohrglanzgras, 2016).

8 FERTILIZATION

The fertilization of paludiculture has not yet been conclusively clarified. According to the current legal situation (Fertilizer Act and Fertilizer Ordinance (DüMV)), fertilization of paludiculture is not permitted, as paludiculture is permanently water saturated! The extent to which fertilization is necessary depends largely on the initial nutrient availability of the site, the nutrient composition, the nutrient content of the inflow water for rewetting, the intensity of use (i.e. number of harvests), and the harvest period. With a single cut in November through February, nutrient removal with harvested biomass is relatively low because most paludiculture species have translocated nutrients from the aboveground biomass back into the roots and rhizomes. The low nutrient removal can normally be easily covered by the continuously water supply for rewetting. The situation is different when, for example, reed canary grass is managed with two cuts per year and used as a substrate for biogas production. Here, very large amounts of nutrients are removed from the site in the summer harvest. In regions with nutrient-polluted surface waters, this can possibly still be compensated for, but with a moderate nutrient load, soil impoverishment and a decline in yields will be the result in the short- or long-term. Lowering the groundwater levels at the time of cutting at the beginning of July, followed by a fertilizer application, leads directly to a reactivation of the peat mineralization, which massively reduces or negates the GHG reduction potential. It must also be considered that very long periods of time are required until the topsoil of the peat body has sufficiently dried out so that organic or mineral fertilizers can be applied or incorporated without hesitation. In addition, the low water level following fertilizer application must be maintained for a very long time to prevent significant nitrate, sulfate and phosphorus leaching and denitrification N-losses. This topic is currently being investigated in the joint project "Nachhaltigkeit von Paludikulturen unter besonderer Berücksichtigung des Stoffhaushaltes (NAPALU, funding code: 2221MT010A to G)".

In most arable and grassland sites, the initial nutrient content in the soil is very high so that yield losses due to nutrient deficiency in the first growth years are not to be expected. However, it should be noted that potassium fixation could occur when grassland is plough on fen peatlands. This can lead to yield losses in reed canary grass and cattail paludicultures if the inflow water for rewetting does not cover the resulting K deficiency.

It is recommended to determine the nutrient content in the soil before establishing new paludicultures. In addition, the nutrient loads of the potential inflow water should be known in advance. This provides the basis for the selection of suitable paludiculture plant species for a given site. Precise information on the nutrient requirements of the individual paludiculture plant species cannot yet be given. Within the MOORuse-project, fertilization experiments have revealed that the yields of narrow-leaved cattail and reed canary grass can be slightly increased or stabilized by a balanced mineral fertilization on a low nutrient site. In contrast, no significant changes in yields of sedges, broad-leaved cattails and reed could be observed via balanced fertilization. Thus, from the nutrient requirements, the following order can be roughly defined: narrow-leaved cattail > reed canary grass > broad-leaved cattail > slender-tufted sedge > lesser pond-sedge & common reed.

Peatland Science Centre

9 REFERENCES

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.

Beetz, S., Liebersbach, H., Glatzel, S., Jurasinski, G., Buczko, U., Höper, H. (2013): Effects of land use intensity on the full greenhouse gas balance in an Atlantic peat bog, Biogeosciences, 10, 1067–1082.

Birr, F., Abel, S., Kaiser, M., Närmann, F., Oppermann, R., Pfister, S., Tanneberger, F., Zeitz, J. & Luthardt, V. (2021): Zukunftsfähige Land- und Forstwirtschaft auf Niedermooren – Steckbriefe für klimaschonende, biodiversitätsfördernde Bewirtschaftungsverfahren. 148 S. Auszug aus den BfN-Skripten 616, bearb. Fassung. Hochschule für nachhaltige Entwicklung Eberswalde und Greifswald Moor Centrum (Hrsg.). Eberswalde, Greifswald.

Drösler, M. (2005): Trace gas exchange of bog ecosystems, Southern Germany. Technische Universität München, Freising, 2005.

Flyer Rohrglanzgras 2016, Greifswald Moor Centrum, https://www.moorwissen.de/pflanzen-nutztierarten.html

StMELF (2023): Merkblatt zur Umwandlung von Dauergrünland, Genehmigung gemäß §5 des GAP-Konditionalitäten-Gesetzes (GAPKondG) und Ausnhamen nach Art. 3 Abs. 4,5 Bayerisches Naturschutzgesetz (BayNatSchG), Anzeige der Umwandlung von ab dem 1. Januar 2021 entstandenem Dauergrünland gemäß § 6 GAPKondG.

Tiemeyer, B., A. Freibauer, E.A. Borraz, J. Augustin, M. Bechtold, S. Beetz, C. Beyer, M. Ebli, T. Eickenscheidt, S. Fiedler, C. Förster, A. Gensior, M. Giebels, S. Glatzel, J. Heinichen, M. Hoffmann, H. Höper, G. Jurasinski, A. Laggner, K. Leiber-Sauheitl, M. Peichl-Brak, M. Drösler (2020): A new methodology for organic soils in national greenhouse gas inventories: Data synthesis, derivation and application. Ecological Indicators, 109, (2020), 105838.

Tiemeyer, B., Freibauer,A., Drösler, M., Albiac-Borraz, E., Augustin J., Bechtold, M., Beetz, S., Belting, S., Bernrieder, M., Beyer, C., Eberl, J., Eickenscheidt, T., Fell, H., Fiedler, S., Förster, C., Frahm, E., Frank, S., Giebels, M., Glatzel, S., Grünwald, T., Heinichen, J., Hoffmann, M., Hommeltenberg, J., Höper, H., Laggner, A., Leiber-Sauheitl, K., Leppelt, T., Metzger, C., Peichl-Brak, M., Röhling, S., Rosskopf, N., Rötzer, T., Sommer, M., Wehrhan, M., Werle, P., & Zeitz, J. (2013): Klimarelevanz von Mooren und Anmooren in Deutschland: Ergebnisse aus dem Verbundprojekt "Organische Böden in der Emissionsberichterstattung", Thünen Working Paper, No. 15, https://www.nbn-resolving.de/urn:nbn:de:gbv:253-201311-dn052806-7.

UBA 2021 (Umweltbundesamt 2021): Berichterstattung unter der Klimarahmenkonvention der Vereinten Nationen und dem Kyoto-Protokoll 2021: Nationaler Inventarbericht zum Deutschen Treibhausgasinventar 1990-2020. Dessau: Umweltbundesamt (UBA).