MITIGATION MEASURE CATALOGUE
FOR TARGETED AGRO-ENVIRONMENTAL NUTRIENT MITIGATION

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WaterCoG
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MITIGATION MEASURE CATALOGUE
FOR TARGETED AGRO-ENVIRONMENTAL
NUTRIENT MITIGATION
is produced by

Danish Agriculture & Food Council F.m.b.A.
SEGES
Agro Food Park 15
8200 Aarhus N
8740 5000
seges.dk

AUTHORS
Jakob Sølvhøj Roelsgaard, Consultant
Camilla Husted Vestergaard, Consultant
Sebastian Piet Zacho, Consultant
Flemming Gertz, Chief Consultant,
Aquatic Environment
Irene Asta Wiborg, Vice of Department
Frank Bondgaard, Senior Consultant
Kristoffer Piil, Consultant
Søren Kolind Hvid, Senior Consultant
Simon Rosendahl Bjorholm, Special Consultant
Charlotte Kjærgaard, Chief Scientist
Trine Eide, Chief Planner

PHOTOGRAPHY
Ann Birgitte Thing, LandboNord
Flemming Gertz, SEGES
Frank Bondgaard, SEGES
Henrik Skovgaard, Orbicon
Jørgen Kaarup, Straatagets Kontor
Ole Hyttel, The Danish Nature Agency
Peter Bondo Christensen, Aarhus University
Charlotte Kjærgaard, SEGES
Jimmi Spur Olsen, Vordingborg Municipality
Jonas Brønd Nielsen, former trainee
Frans Novak Knudsen, Fulden Film
ISO Film
Rambøll
Mads Fjeldsø Christensen
Jeroen Geurts, Radboud University
J. Pijlman, Radboud University
C. Fritz, Radboud University
Sofie van't Veen, BioScience
Morten Schultz, ISO Film

COVER PHOTO
Danish Agriculture & Food Council

ILLUSTRATIONS
Lars Nørregaard, Grafisk Design, Glostrup
Trine Eide

DESIGN & LAYOUT
Marianne Kalriis-Nielsen

1. version 2017
English version 2021 with help
from WaterCoG project

Contact your consulting firm when you plan to initiate a targeted environmental measure on your farm. Please note that many environmental measures require approval by the municipality before execution.

More information on targeted environmental measures: *virkemiddelkatalog.dk*

The following research projects have contributed to this catalogue (Danish Strategic Research Council and Green Development and Demonstration Programme): *Supreme-Tech, BufferTech, TReNDS and iDRÆN*

Contacts at Water Environment, SEGES


Chief Consultant, Aquatic Environment
Flemming Gertz
+45 8740 5418
flg@seges.dk


Special Consultant
Simon Rosendahl Bjorholm
+45 8740 5432
sibj@seges.dk


Senior Consultant
Frank Bondgaard
+45 8740 5409
fbo@seges.dk


Consultant
Sebastian Piet Zacho
+45 8740 5563
seza@seges.dk

TARGETED ENVIRONMENTAL MEASURES ON YOUR FARM

This catalogue provides you with a range of targeted environmental measures, and focuses on the **location, design and effect** of such measures at the border of cultivation land. These are measures that can help reduce the discharge of nutrients from fields and thus improve the condition of our aquatic environment, while also having other positive side effects.

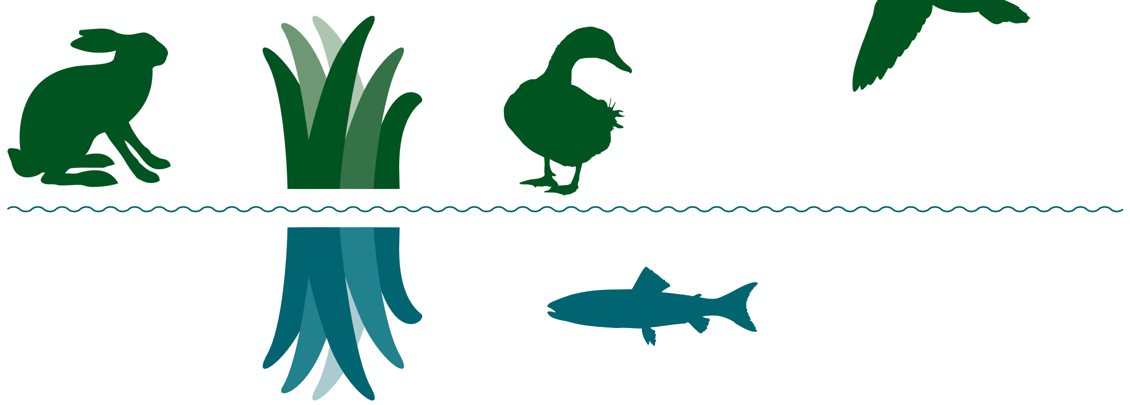
The topography of your farm is crucial in terms of the environmental measures that are appropriate for you. It is important to investigate which measures can be sited on your land so that they provide maximum benefit without disrupting other field operations. Some measures have the greatest effect on undulating areas, while others work best on flat land. It is imperative that the environmental measures do not create a backwater in the drainage systems. Drainage water always needs to be drained quickly, either by the natural slope of the terrain or by pumping the water away. However, this does not apply to lowland projects.

There are many ways to establish environmental measures, and **it is important that they are integrated naturally into the surrounding terrain**. Organic forms and planting often mean that environmental measures are integrated more naturally into the landscape. The environmental initiatives will serve as habitats for many different species and often provide good hunting opportunities and cover for wildlife. If you have livestock production, you should be aware that specially protected species can establish themselves in or through environmental measures. This relationship may affect future environmental approval. Discuss this situation with your consultant.

Many farms often have **less productive land** in the form of wet depressions in the field, sunken drains, wedges in the field, headlands, fallow land, tree shade, etc. You should consider whether it is possible to initiate a targeted environmental measure in these areas.

Wetlands and mini wetlands with open basins are now approved environmental measures, while others presented here are still pending, so consider some of the measures in this catalogue as **a glimpse into the future**. It is an advantage to use approved environmental measures so that the effect can be credited.

Look at the illustrations and find inspiration for what will work on your farm. Always contact your municipality when you intend to establish a targeted environmental initiative. A productive discussion is always a good first step.



PAGE CONTENTS

ICON KEY

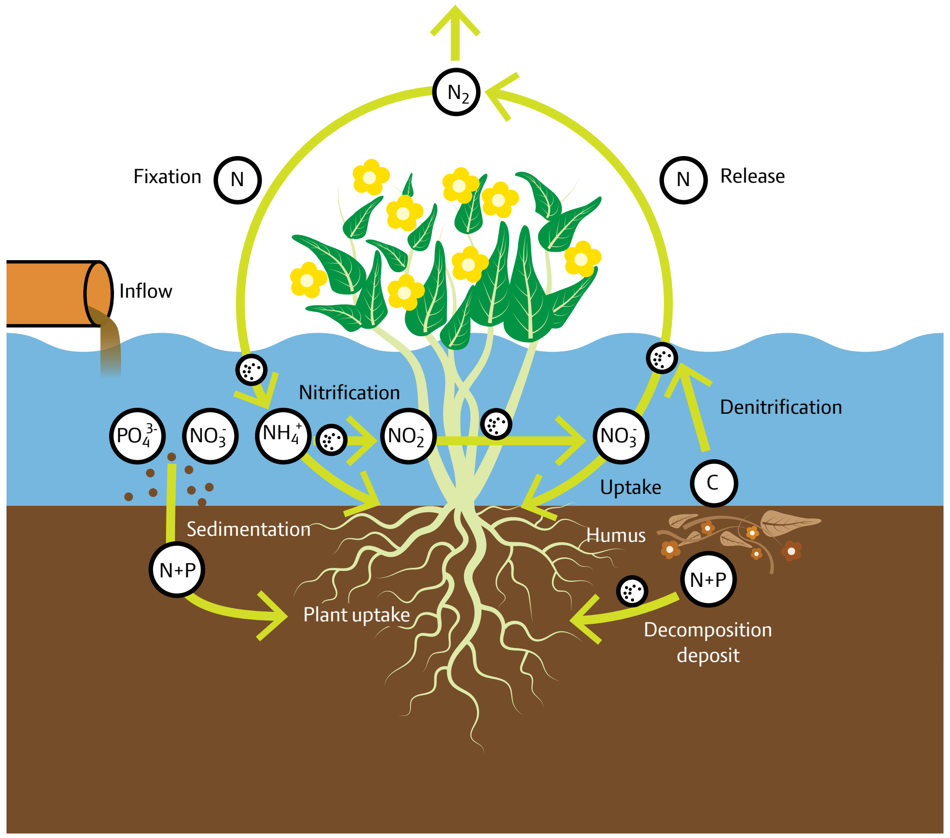
N&P effect | P effect | Undulating terrain | Flat terrain | Drained soil | Compen-sation | No compensation | Approved effect | Localisation

TARGETED ENVIRONMENTAL MEASURES
THIS IS HOW THEY WORK

The effect of targeted environmental measures is controlled by various chemical, physical and microbial processes depending on the specific measure. For further details, see the explanation at the back of the catalogue.

The target of environmental measures is to reduce the discharge of nutrients in drainage water from tile drained fields. The effect depends on a wide variety of conditions, such as the nutrient loads, water retention time, redox conditions, temperature, pH and plants.

The most important retention processes are sedimentation and deposition of particle bound phosphorus, plant uptake and nitrogen reduction by microbial denitrification. Read more about the concepts in the explanation of environmental effects at the back of the catalogue.



The illustration shows the major reduction and retention processes for nitrogen (N) and phosphorus (P) in wet environments receiving drainage discharge from agricultural fields. Nitrogen is discharged from tile drains mainly as nitrate (NO_3-N), while P which is found as both soluble phosphate (PO_4-P) and particle bound P (PP).
The main processes of retaining P in mitigation measures targeting drainage water are sedimentation of PP and/or sorption as well as plant uptake of PO_4-P. In contrast NO_3-N is reduced in the anaerobic environment by microbial denitrification and released to the atmosphere mainly as free gaseous N_2 In general plant uptake of nutrients is considered temporary unless biomass is harvested which ensures a permanent removal of nutrients.

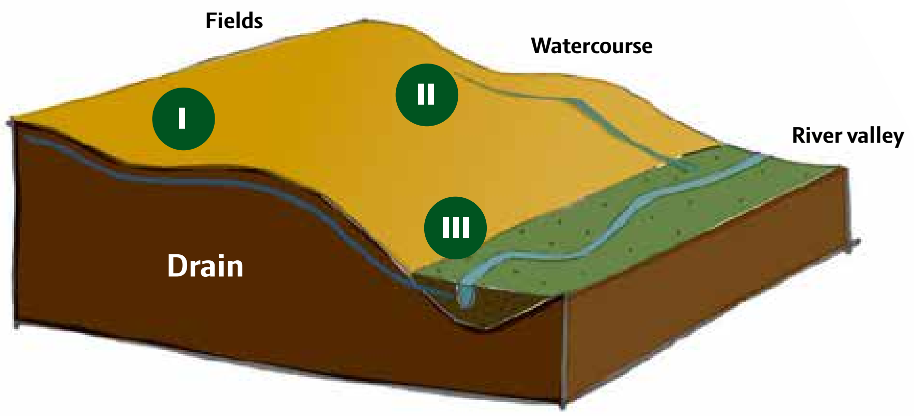
WHERE TO LOCATE TARGETED DRAINAGE MEASURES

More than half of the Danish agricultural land is drained by subsurface tile drains. Drainage is essential for cultivating the soil. However, subsurface tile drains may also constitute rapid highways for transport losses of nutrients, nitrogen (N) and phosphorus (P) into the aquatic environment. Together with drainage of wetlands, drainage of agricultural land has contributed to a loss of the natural capacity of landscapes to retain and convert nutrients. The Danish catchments has therefore lost the former retention capacity, and thus the aquatic environment is affected to a greater extent by our cultivation of agricultural land.

The essence of targeted drainage measures is basically to regain and increase the natural retention capacity of landscapes by (re-) establishing so-called filters in the landscape. Drainage / landscape filters captures nutrients from agricultural fields and reduces the nutrient loads to vulnerable aquatic environments. In the recent years an increasing research effort has accomplished the documentation and acceptance of a range of new drainage / landscape filters.

The vision of targeted drainage measures are the implementation of variable measures locally adapted to the specific transport pathway, where critical nutrient loads exceeds environmental targets. The measures essentially make use of the same natural retention and reduction processes that exist in different parts of the landscape.

MITIGATION MEASURES APPLIED TO THREE LANDSCAPE ELEMENTS



This mitigation measure catalogue distinguishes between measures that target drainage transport in three landscape elements:

I Measures implemented within upland areas
II Measures adapted to the buffer zone along watercourses
III Measures adapted to lowlands in the river valley

Drainage measures implemented in upland areas in connection with tile drains

In drained upland areas, there is often not the same natural conditions for removing nutrients as in the wet lowland soils. However, small local wetlands or reestablishment of former wetlands in wet field depressions can be used to restore part of the natural landscape filters. In areas where there are no natural landscape filters available, construction of drainage filters such as surface-flow wetlands or biofilters can be designed to effectively retain and remove N and P from agricultural drainage water.

In areas with discharge of ochre (known as ochre areas), well-known ochre precipitation basins can contribute to the mitigation of nutrient losses especially with high effect of P retention. Ochre precipitation basins are typically established as end of pipe or open ditches as well as basins within smaller watercourses.

Drainage filters can potentially be placed anywhere in the landscape where there are drained areas. In flat areas, the establishment of drainage measures typically requires solutions connected to pumps.

MINI WETLAND WITH SURFACE FLOW

VIEW FILM
Mini wetland areas
with open basin

A mini constructed wetland with surface-flow is established adjacent to the main drain pipe. During operation drainage water is discharged through a sequence of deep open basins and shallow vegetation zones, where sedimentation, sorption and microbial processes reduces the drainage load of N and P.

LOCATION AND ESTABLISHMENT

The mini wetland is required to have a size of 1% of the drainage catchment and is prioritized for drainage catchment of minimum 20 hectares to be cost-effective solutions. The design of the wetlands must be adapted to the slope of the terrain to prevent any accumulation or backflow in the drain. Often, the mini wetland will be placed as end of pipe solutions.

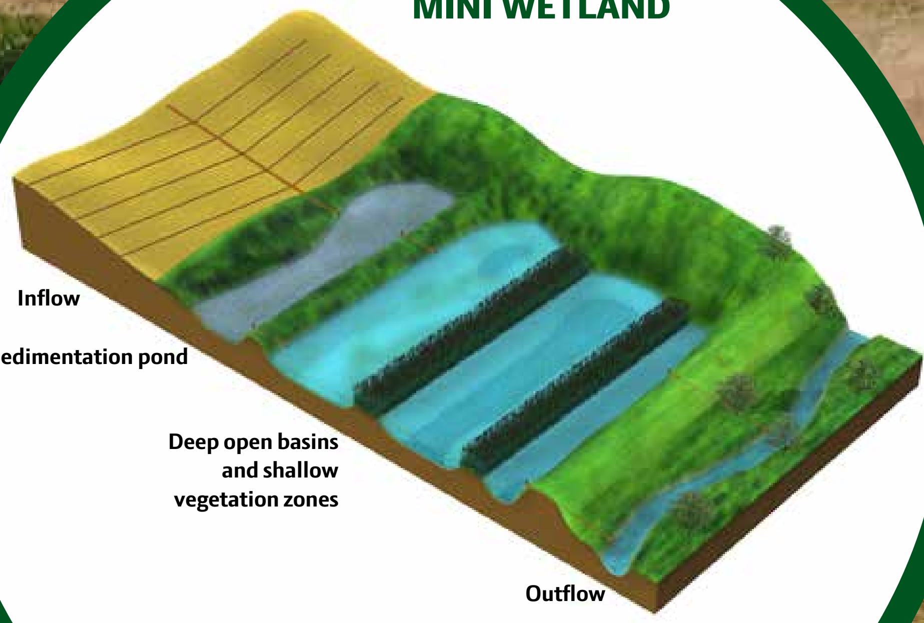
OTHER BENEFITS

A mini wetland area creates a habitat for plants, amphibians, insects and small animals; and it increases biodiversity and hunting opportunities in the immediate area. The initiative has additional potential as backwater basins, which are useful for climate adaptation.

COST

Establishment costs are typically in the order of DKK 100,000-300,000 for 1 hectare of mini wetland.

DESIGN OF SURFACE-FLOW MINI WETLAND



Drainage water is discharged into a sedimentation pond where particles and P bound to particles are deposited. Following the sedimentation pond, the water passes through the sequence of deep open and shallow vegetation zones in the wetland, where nitrate-N is converted to free atmospheric nitrogen (N_2) by microbial denitrification. The cleaned drainage water is finally returned into the watercourse.

N-EFFECT

Average 25% annual N reduction within a 15-40% range depending on seasonal variation in drainage discharge.

P-EFFECT

An average of 40-50% annual P retention within a 20-80% range.

COMPENSATION

From 2018, compensation is available for establishment under Landdistriktsprogrammet (the Rural Development Programme). (2017/18-2020).

MINI WETLAND WITH SURFACE-FLOW SITUATED IN A FLAT TERRAIN

VIEW FILM
Mini wetlands with open basin

NP

In flat landscapes construction of mini wetlands with surface-flow is similar to the general conditions for mini wetlands, except that installation of a pump is often required to facilitate the discharge of drainage water from the field through the wetland.

N-EFFECT

On average 25% annual N reduction but within a 15-40% range depending on seasonal variation in the drainage discharge.

P-EFFECT

Average 40-50% annual P retention within a 20-80% range.

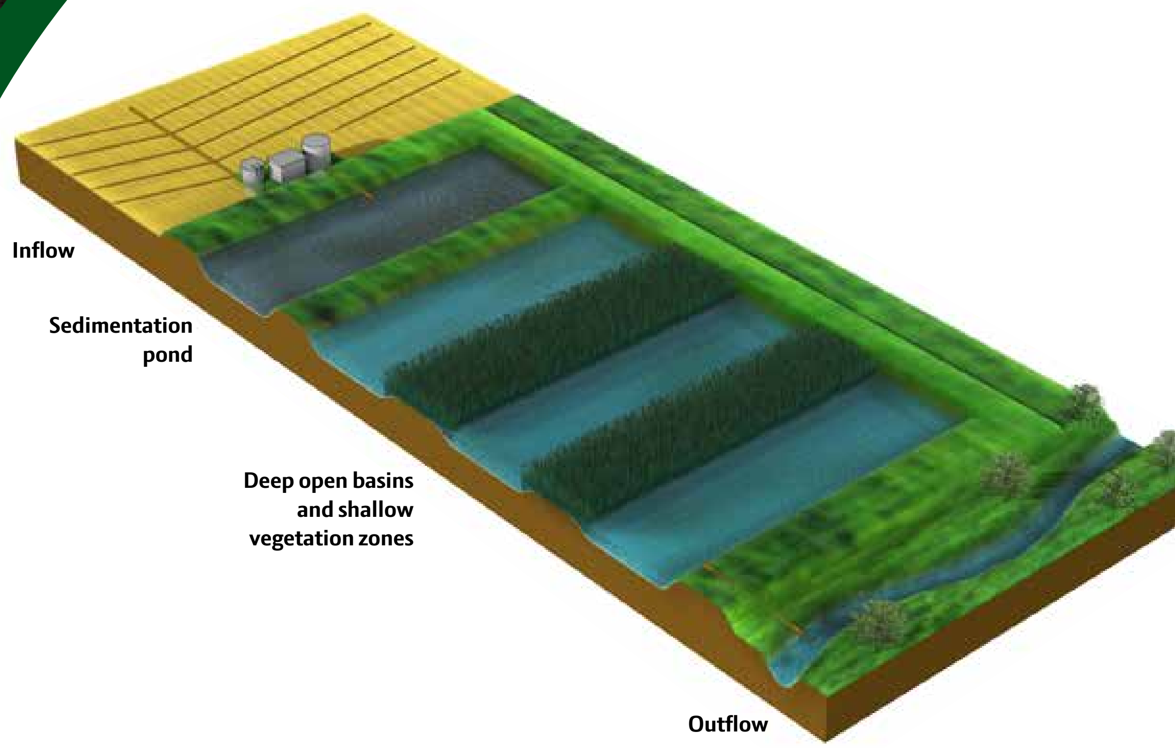
LOCATION AND ESTABLISHMENT

Mini wetlands established with a pump solution is especially adapted to flat terrain. All other conditions are similar to the general establishment of mini wetlands.

OTHER BENEFITS

A mini wetland with open basins can be adapted to the landscape to combine nature and production, creating habitats for insects and amphibians as well as wildlife and plants.

DESIGN OF MINI WETLAND



To prevent water from flowing back into flat terrain, the inflow water is raised into a sedimentation pond by means of a pump, where particles and PP are deposited. Following the sedimentation pond, the water passes through the sequence of deep open and shallow vegetation zones in the wetland, where nitrate-N is converted to free atmospheric nitrogen (N_2) by microbial denitrification. The cleaned drainage water is finally returned into the watercourse.

COMPENSATION

From 2018, compensation will be available for establishment under Landdistriktsprogrammet (the Rural Development Programme). (2017/18-2020).

WETLAND WITH BIOFILTER

VIEW FILM
Biofilter
wetlands

A biofilter wetland with wood chips is established in continuation of the drain pipe and serves as an effective filter for reducing nitrate. The advantage of biofilter wetlands is that they can remove more effectively high amounts of N in a small area.

COST

Establishment costs are typically in the range of DKK 200,000-400,000 for 1 hectare.

LOCATION AND ESTABLISHMENT

Biofilter wetlands need to be constructed with a hydraulic gradient, thus a slight height difference between inflow and outflow pipes. Biofilter wetlands with basin depths of 1 m require an area of approx. 0.25% of the contributing drainage catchment. The biofilter wetland can be constructed with an initial storage pond with variable water level to reduce the hydraulic loading rate into the wood chip filter.

OTHER BENEFITS

A biofilter wetland can create habitat for plants, amphibians, insects, and small animals. Biofilter wetlands can be integrated with climate protection measures.

The biofilter wetland iDRÆN project at Odder.

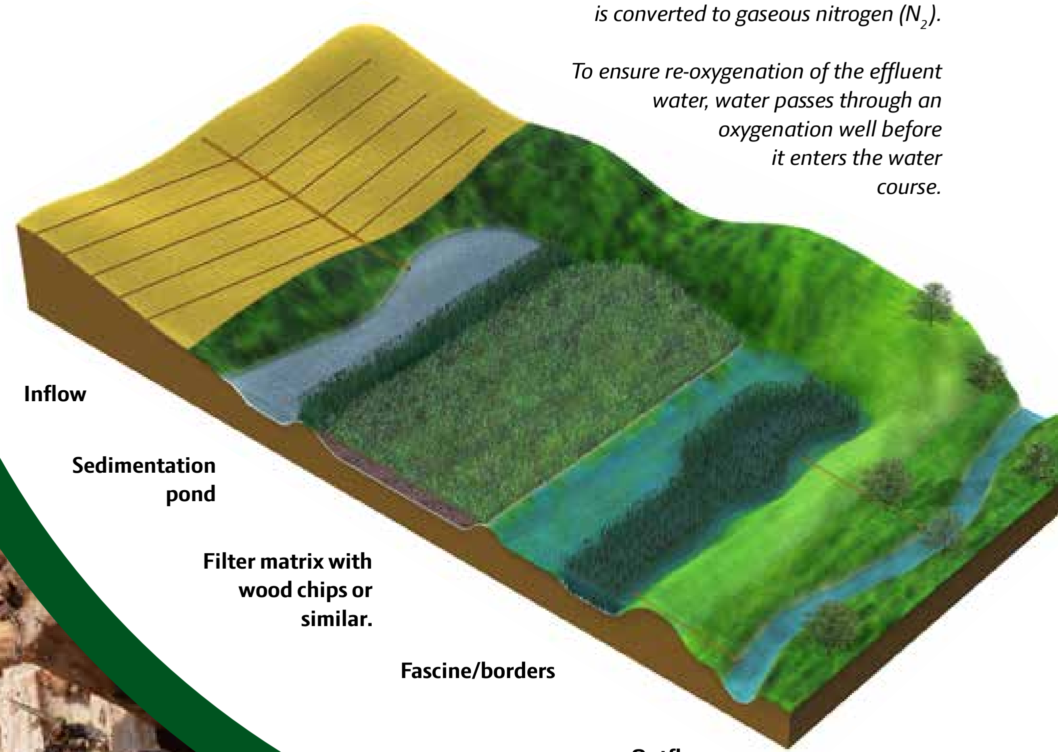
EFFECT

With the correct design and dimensions, a biofilter wetland can reduce N in drainage water by 50-70%.

DESIGN OF BIOFILTER WETLAND

The drainage water is discharged into a sedimentation pond or a sedimentation well, where sediment and particle-bound P are deposited. Following the sedimentation pond, the drainage water passes through a water-saturated wood chip filter matrix, where nitrate-N is converted to gaseous nitrogen (N$_2$).

To ensure re-oxygenation of the effluent water, water passes through an oxygenation well before it enters the water course.



Planted matrix mini wetland fits naturally in the landscape..

Willow wood chip does not colour the drainage water.

ENVIRONMENTAL MEASURES AND THE LANDSCAPE

Establishing environmental measures can have a local impact on the landscape – not only visual, but also with regard to factors such as nature, accessibility and hunting. Not every location will have equal importance, but it should be noted that there may be places where special consideration should be given to the landscape values.

Particular care should be taken when:

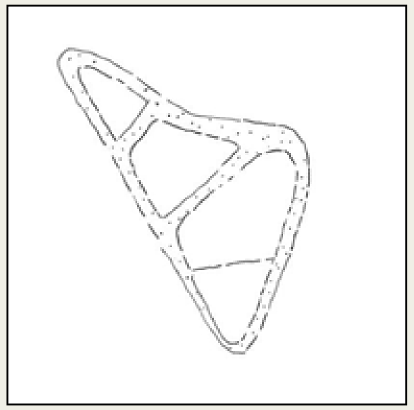
- it is a very hilly terrain
- the area is described/designated as valuable and worthy of nature conservation
- it is very visible and/or is in an area with many visitors.

There are good opportunities to modify the wetlands so that they contribute positively to the landscape, as well as having potential for nature, hunting and recreation. A deliberate and well-documented strategy for modification of the landscape can also be a good starting point for dialogue with authorities and land owners.

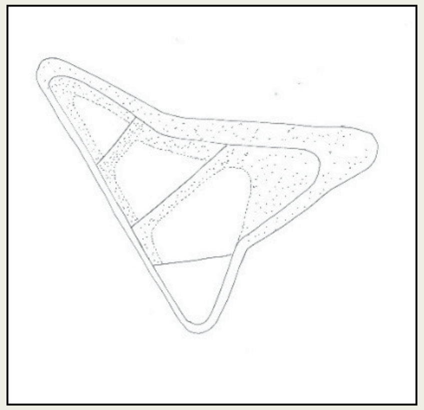
Elements that may be important in terms of the wetland's impact on the landscape can be:

- the shape and coherence of the wetland in its surroundings – is it organic, or does it appear more technical and angular?
- placement of the basins relative to each other and the terrain – are they level, do they follow the terrain in terraces, or has the terrain itself been altered to a greater or lesser extent?
- the incline on the sides of the basins may also have an impact on planting and also on safety. Getting out of the basins should be easy
- planting in and around the basins – species (native), composition, density, etc.

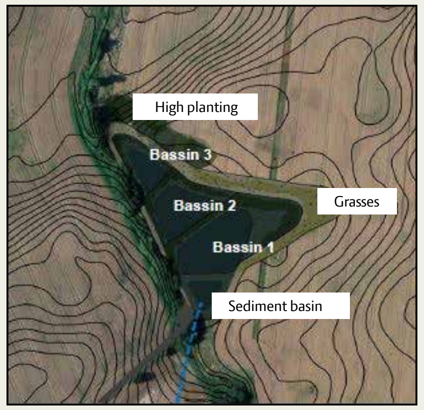
The installations should of course be designed to meet the functional requirements; but it is possible, with simple modifications, to adapt the installations more naturally to the landscape.



Organically-shaped wetland, partly adapted to the terrain but without areas for planting or other purposes.



With a slightly larger area, there is an opportunity for further natural adaptation to the terrain, planting, grasses or trees – and the possibility of access.



Becomes a more natural element in the landscape over time.

Visualisation of the mini wetland showing how, with modification, it can blend very naturally into the landscape.

- Design *with* the landscape not *against* it – adapt to terrain and existing vegetation.
- Think in organic forms and avoid excessive interference with the terrain.
- Prevent the wetland from appearing too technical and angular. If necessary, it could be adapted so that it appears in precise and sharp contrast to the landscape. Shielded planting can also be an option.
- Think in stages – the system can take time to develop. Consider what it will look like in five or 10 years.
- If possible, design with multiple objectives/functions.

NUTRIENT REDUCTION IN OCHRE PRECIPITATION PONDS

N-EFFECT

Average N reduction is 7.7% but with variations from -42 to 47%.

P-EFFECT

Average P retention is 40%, but with variations from 20-62.

Ochre precipitating ponds are constructed in smaller streams, creeks and ditches to reduce ochre load downstream. Well-functioning ochre ponds can be very effective at retaining phosphorus and further reduce nitrogen.

Ochre ponds are established in smaller streams, brooks or ditches where the water is passing a sequence of open deeper basins incepted by shallow vegetation zones . Plants such as water crowfoot and water star with large surface areas are recommended. The surface area of the plants contributes to catalysing the oxygenation of dissolved ferrous iron to ferric iron (ochre), which simultaneously binds and precipitates dissolved P. Ochre ponds require regular maintenance by removing ochre sludge and ensuring a suitable vegetation filter.

LOCATION AND ESTABLISHMENT

Potential ochre areas are found in smaller streams, brooks and ditches in West and Southern Jutland, Denmark. The best-performing ochre ponds are shallow water weed-filled basins with deep sedimentation basins at the inflow and outflow. Ochre ponds must be dimensioned to obtain a hydraulic residence time of approximately 20 hours, and pH of the water pH should be ≥6 for the ochre precipitation to be effective.

OTHER BENEFITS

The primary purpose of an ochre system is to reduce the ochre load and improve the quality of larger watercourses downstream. The systems have further potential as storage ponds in connection with climate adaption.

Aerial photo of an ochre precipitation pond.

SMALL LOCAL WETLANDS

IN FIELD DEPRESSIONS

Small local depressions within fields, which have either been former small wetlands or still retain the features of a small wetland, can serve as local nutrient filters. Small local wetlands on drained areas can contribute to removal of N in drainage water, therefore being a local alternative to specially constructed mini wetlands.

Small local wetlands are based on natural local conditions in the form of field depressions. Allowing field drainage water to pass the small wetlands can contribute to N removal in drainage water by microbial denitrification. Wetlands situated in carbon rich soils have the best conditions for reducing nitrate-N to free atmospheric nitrogen (N_2).

LOCATION

Small local depressions or small wetlands are prevalent in the Danish countryside. Attempts have frequently been made to drain such small in-field wetlands, but in some cases the depressions are wet and may have developed into small local wetlands in the field or at the edge of the field. Historical maps can show the characteristics of former local wetlands.

OTHER BENEFITS

Small local wetlands can contribute to small biotopes for plants, amphibians, insects and small animals and increase biodiversity and hunting opportunities in the immediate area.

N-EFFECT

The N effect is expected to be in the same order of magnitude as mini wetlands with surface-flow. For wetlands situated on carbon-rich soils the effect is expected to be greater, corresponding to 20-50%.

P-EFFECT

Small local wetlands can act as sedimentation ponds for particulate P in drainage water.

Small, local wetland.

WHERE TO LOCATE TARGETED DRAINAGE MEASURES

Drainage measures located in the buffer zone along a watercourse

In drained areas bordering the watercourse, the buffer zone along the watercourse can sometimes be used to establish drainage filters in the form of integrated buffer zones, where drains are disconnected allowing the drainage water to pass through an open basin followed by infiltration through a planted buffer zone, thus reducing the drainage water's content of both N and P before the water enters the stream.

Other measures that can be used for nitrogen reduction in the buffer zone are **saturated buffer zones**, where the drainage water through drainpipes is distributed along a larger buffer zone area parallel to the watercourse and slowly seeps into it by infiltration via the saturated soil. Other measures that may have an effect on nutrients include **mini-river valleys** and **two stage ditches**.

INTEGRATED BUFFER ZONES

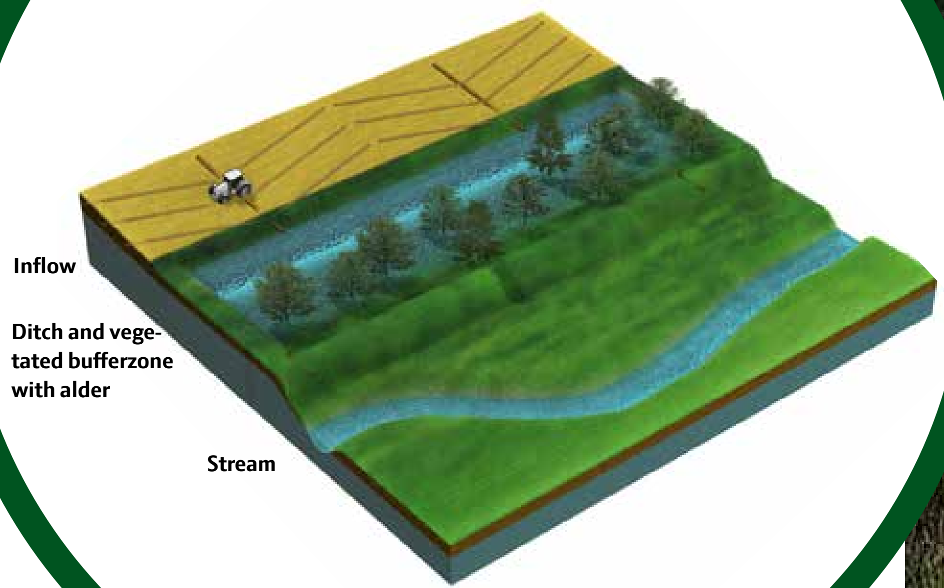
VIEW FILM
Integrated buffer zones

Integrated buffer zones (IBZ) are constructed in the same area as traditional buffer zones. IBZs are constructed by disconnecting the tile drain and allowing the drainage water to pass through a ditch / open pond placed parallel to the stream. Overflow from the pond is distributed along the vegetated buffer zone, and allowed to infiltrate into the wet buffer zone before discharging into the stream. Phosphorus is retained by sedimentation of PP and sorption of soluble P, while N is removed by microbial denitrification in the pond and the wet buffer zone. The vegetation will further take up nutrients in the growing season, and by frequent harvesting of the biomass nutrients are permanent removed.. IBZs are also effective in areas where there is significant soil erosion from sloping fields as the pond function as a sediment trap.

LOCATION AND ESTABLISHMENT

Integrated buffer zones are established in the area between the field and stream and in fields with drainage. It is important that the landscape inclines and there is a slope down to the stream to prevent any backwater in the drainage system, and allow hydraulic gradients suitable for soil infiltration. The design and size of an integrated buffer zone is highly dynamic and depends on the landscape and catchment. It is recommended that the ditch that collects the drainage water constitutes 1 per cent of the catchment.

DESIGN OF INTEGRATED BUFFER ZONES

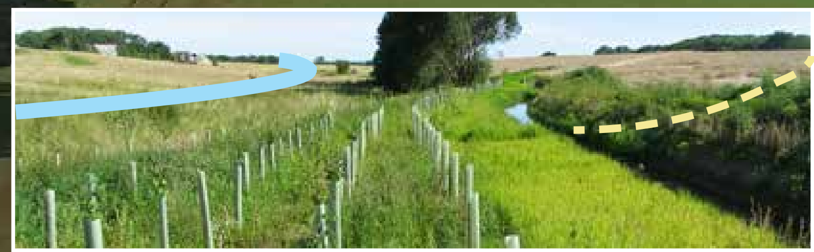


COST

The cost will vary mainly due to the different excavation requirements, which depend on the location. Approximately DKK 50,000-100,000 per continuous 100m incl. plants.

OTHER BENEFITS

- Reduces the transport of sand, silt and ochre into a stream;
- Allow recirculation of P from ditch back to field;
- Reduction of P from the buffer zone, when the biomass-P is harvested approx. every 15 years;
- Alder along a stream reduces bank erosion, which is a major source of P loss into the aquatic environment;
- Trees along streams reduce the water temperature in streams and add leaves and twigs which increase diversity in the stream;
- Trees along the water shade fast-growing aquatic plants;
- Climate adaptation in the form of a delay to runoff water during heavy rainfall;
- Greater biodiversity along the stream and better hunting opportunities.
-



Integrated buffer zone at Odder. The blue lines represent the stream and the yellow dotted line is the drainage inflow.

EFFECT

N effect: 20-40%

P effect: 30-70%

INTEGRATED BUFFER ZONES

The system will develop over time. When the vegetation is well established, it will appear more natural.

Vegetated integrated buffer zones situated along the stream course integrated almost become part of the natural landscape.

The hydraulic gradient, determined by the difference in water level between the pond and the stream, integrated is important for ensuring a proper infiltration of the drainage water though the buffer zone soil. For clay soils with low hydraulic conductivity, the hydraulic gradient must be larger, compared to more light textured soils for the same infiltration area.

SATURATED BUFFER ZONE

SE FILM
Mættede
randzoner

A saturated buffer zone is typically a lower lying area bordering the field and the stream. By disconnecting the tile drain and allowing the drainage water to distribute and infiltrate into the water saturated buffer zone soil, nitrate N is removed by microbial denitrification.

LOCATION AND ESTABLISHMENT

Areas suitable for saturated buffer zones are lowland areas in river valleys or buffer zones located in landscapes with sloping terrain between the field and the stream, thus allowing hydraulic gradients for drainage water infiltration into the wet buffer zone soil. Saturated buffer zones typically constructed by disconnecting the tile drains and ensuring distribution of water and water level with a control well. Clay soil with low hydraulic conductivity is generally not suitable for saturated buffer zones due to limited water infiltration.

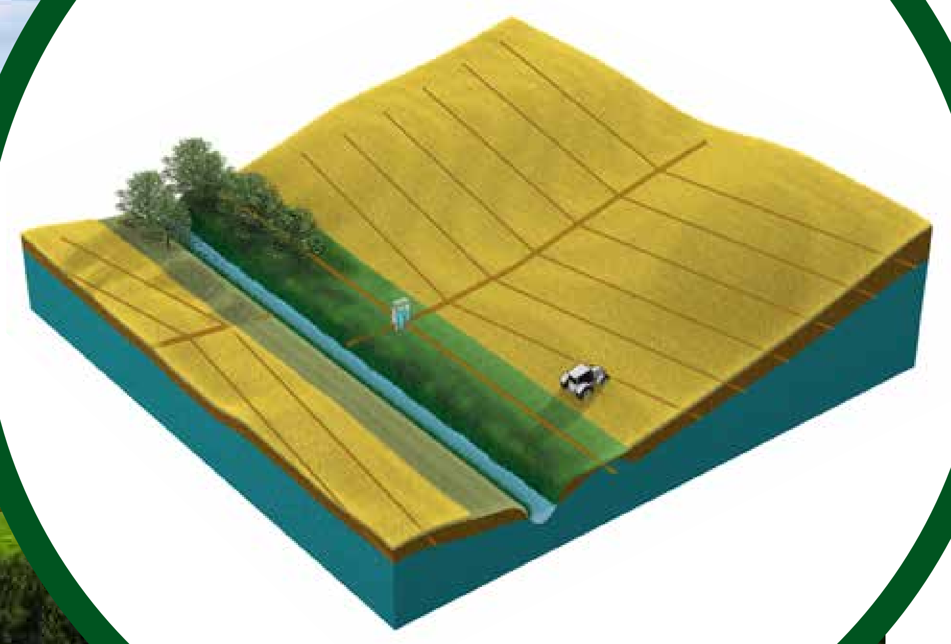
OTHER BENEFITS

Saturated buffer zones allow biomass production in the buffer zone, which can provide cover and food for the field's wildlife. Further, harvest of biomass contributes to the permanent removal of nutrient especially P, that is otherwise retained within the soil and biomass. The disadvantage is that the area may become swampy, hindering field traffic. Control wells may, however, be constructed to allow raise and lowering of the water level in the buffer zone.

COST

Saturated buffer zones are generally cheap environmental measure, however restricted to specific landscapes and soil conditions.

DESIGN AF SATURATED BUFFER ZONE



Control well and perforated subsoil drain which raises the water level in the buffer zone.

EFFECT

The nutrient effect of saturated buffer zones will typically correspond to the N and P effects found for wetland restoration projects with drainage water infiltration.

Local effects depend on soil type, hydraulic loading rate and flow-pathway. Infiltration in carbon rich soils generally demonstrated N removal from 50-100%, while lover removal efficiency is observed in more sandy soils or areas with surface run-off. P effects depends on the ratio between P retention mainly from sedimentation and in situ P release of Fe-bound P. In Denmark estimating P effects from local wetting projects are mandatory.

Perforated drainpipe packed with straw to prevent sand penetration.

Control well where the water level can be raised and lowered. .

TWO-STAGE DITCH

A two stage ditch is established as a two-level trench. The environmental measure reduces the speed of the water as the ditch is made wider. The advantage is that as the speed of the water reduces, the clay particles settle, and the nutrients can be better absorbed by plants on the banks.

EFFECT

No Danish documentation on nutrient effects is yet available, but two-stage ditches are used as an environmental measure in Sweden and Finland.

LOCATION AND ESTABLISHMENT

The dimensions of the two-stage ditch depend on the water discharge, the conditions in the area and the soil type.

OTHER BENEFITS

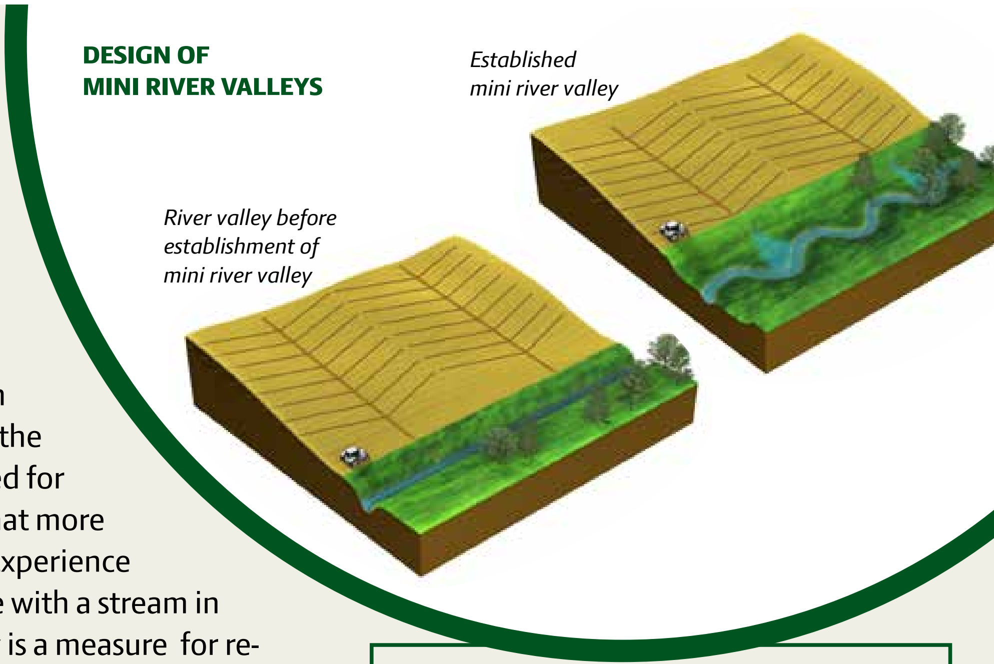
Some two-stage ditches were established in Denmark some years ago with the primary aim of improving drainage and taking the environment into account. This minimises the risk of flooding and erosion. It can also function as landscape corridors and habitats for flora and fauna.

COST

There are costs for cleaning the banks because of sedimentation of clay particles.

Stream before and after the establishment of the two-stage ditch.

MINI RIVER VALLEY



As opposed to a naturally meandering stream the re-meandering of the stream in a mini river valley is kept low and well below field level to allow drains to run. The profile is approximately nine times wider than the width of the stream. Contrary to the two-stage ditch, more space is created for the stream, which is initially somewhat more expensive than a narrower profile. Experience shows that maintenance is negligible with a stream in a mini river valley. A mini river valley is a measure for restoring small streams and ditches, but the effect of nutrient removal is not documented.

EFFECT

The effect on nutrient reduction has not been documented in Denmark. Mini river valleys ensure good drainage with minimal maintenance. Trees and tall bushes will shade the narrow stream and thus ensure that plants in the stream do not impede the drainage of fields in the growing season.

LOCATION AND ESTABLISHMENT

Mini river valleys should preferably be located in narrow streams or ditches as the excavations required otherwise will be too high.

OTHER BENEFITS

A mini river valley creates a habitat for trees, plants, amphibians and small animals and increases biodiversity and hunting in the locality. Tree growth in a mini river valley will create good wildlife cover over time.

Newly established mini river valley with emerging tree growth.

WHERE TO LOCATE TARGETED DRAINAGE MEASURES

Drainage measures on lowland in river valleys

Lowland areas of a river valley form the transition zone between upland agricultural areas and steams or lakes. Such areas are often discharge areas for groundwater and typically have a high groundwater table. Lowland areas in river valleys receive nutrients from agricultural areas via drainage water and groundwater from the contributing catchment area. In catchments dominated by clay soil, the primary transport of nutrients is by tile drainage transport, while in sandy catchments, the contribution from groundwater will be greater.

As transition zones between upland agricultural areas and surface waters, lowland areas in river valleys exert a major control of the overall nutrient balance of the catchment. Lowland areas intercepting nutrients losses from upland agricultural areas may constitute natural landscape filters retaining and/or converting the nutrients, thus reducing the nutrient loads to the surface waters. Restoring wetlands allowing waters from the upland agricultural areas to intercept with the wetland soils, thus restore the natural capacity of the landscape to filter nutrients.

It is not always possible to re-establish a large wetland environment in a river valley and, as an alternative, smaller measures where local drainage is blocked at the base of a slope and drainage water irrigates the wet lowland area can work as a stand-alone measure that reduces the N load from the drained areas to the surface waters. Finally, nutrients can be removed by harvesting biomass. This is particularly important in terms of removing and possibly recirculating P that is retained in the lowland soils. Thus, harvesting biomass will gradually minimise the risk of P being released from the lowland soil through the re-establishment of wetlands. On wet lowland areas, paludiculture can contribute to biomass production and nutrient removal.

WETLAND RESTORATION

VIEW FILM
Wetlands
– a farmer's experience

Wetlands have beneficial effects on the environment and nature, and it can make economic sense to take part in a major wetland project. It is important that when embarking on a wetland project, landowners and authorities adopt an open mind and are prepared to find the right solutions in a constructive manner.

Largescale wetland projects with many landowners will involve redistribution of land among landowners. The projects can provide the opportunity for acquiring a share of land which is safer for cultivation or for improving the economy instead of low-lying areas where drainage has become difficult, and the soil has become wet.

There are several types of wetlands with different main purposes, and each connected to specific Danish subsidy program. All wetlands will to some extent give benefits to both phosphorous, nitrogen and CO_2, if well planned. There should be special awareness not to increase p-loads from the wetland when binding capacity in soil changes.

a. **Nitrogen wetlands**
Nitrogen wetlands designed mainly to reduce nitrogen to coastal waters.

b. **Phosphorous wetlands**
Phosphorus wetlands designed mainly to reduce phosphorus upstream lakes.

c. **Extraction of carbon-rich low-lying soil**
Wetlands mainly designed to reduce greenhouse gas emissions on soil with at least 12% organic carbon.

Be familiar with the process
It is important to know that several options are available to landowners when establishing wetland projects. The same measures are used in all schemes. 20-year land registered agreements are made with wetland maintenance.

Taking part in the process is always voluntary and it is worth investigating whether it can be beneficial for the landowner to become part of one of the three options.

EFFECT

Wetland restoration will establish the natural nutrient retention in the landscape. Drains pipes and ditches will be closed in the wetland so that water runs out naturally as groundwater or runoff water.

Water from higher lying areas is directed to the wetland through blocking ditches or drains at the edge of the wetland with the water being distributed across the wetland. A naturally meandering stream can also be restored with the speed of flow reduced. Winter wet laid meadow areas thereby reduce the speed of the water and can retain water temporarily. The amount of nutrients from field drainage water is reduced to lakes and coastal waters by denitrification, sedimentation of clay particles, uptake in plants and livestock grazing.

Read more at www.vådområder.dk

Wetland at Haraldskær in Vejle Ådal.

COMPENSATION
Wetlands are 100% funded by the State and the EU.

DISCONNECTED DRAINS

VIEW FILM
Disconnected drains

Tile drains can be disconnected at the base of the slope between upland agricultural land and lowland areas, thereby allowing drainage water to infiltrate the lowland soil. Nitrate is thus removed before it reaches the stream.

LOCATION AND ESTABLISHMENT

Disconnected drains and the infiltration of drainage water into lowland areas can be deployed in areas where upland drained areas are bordered by lowland areas. Lowland areas with soil containing organic matter have a particularly high N effect.

COST

This is a very inexpensive measure where pipes are disconnected at the base of the slope to lowland. With larger drainage catchments, it will be necessary to create a distribution channel at the base of the slope ensuring drainage water dispersal over a large area. In some cases, it may be appropriate to lead the drainage water into a sedimentation pond that retains particle-bound P before discharging into the lowland soil.

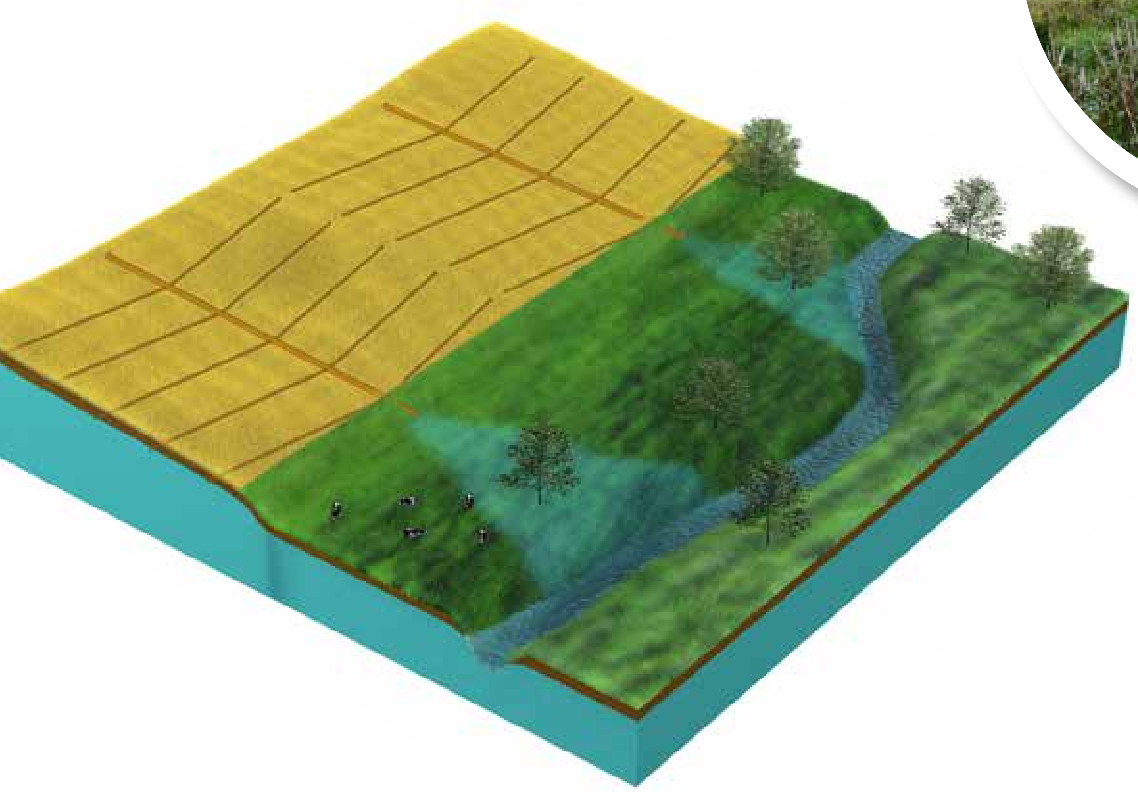
N-EFFECT

Disconnecting tile drains are a part of most wetland projects. Wetland projects involve distribution and infiltration of drainage water from e.g. upland agricultural fields and/or flooding and surface-flow of stream water.

N removal effects are generally high during disconnection of tile drains and drainage water infiltration with average 50% N removal but even higher (50-100%) for organic rich soils with proper infiltration.

To ensure a high drainage water infiltration distribution of drainage water within a larger area can be facilitated by establishing distributor tile and/or ditches at the hill slope.

DESIGN OF DISCONNECTED DRAINS



Disconnected drains at Suså River on Zealand

P-EFFECT

The P effect of disconnecting drains and allowing drainage water to infiltrate can be either positive, neutral, or negative depending on the balance between P retention and in situ P release. Phosphorus in drainage water may be retained by sedimentation of PP and/or sorption of soluble P, however, at the same time there may be an in-situ release of Fe-bound P in the water saturated anaerobic environment. Estimating local P effects is mandatory for rewetting projects in Denmark.

Harvesting biomass from the restored wetlands can contribute to removal of nutrients especially P, which has been accumulating in the soil and biomass.

§ If the river valley is not affected by the Nature Conservation Act's §3 or other form of conservation, there are no regulations to prevent disconnection of drains. If an area is affected by §3 you can probably get permission to block drains by applying to the municipality.

PALUDICULTURE

Paludiculture is the cultivation of wet or semi-wet areas with moisture-tolerant grasses such as canary reed grass, common bulrush, common reed and alder. Blocking is established in drains or ditches to create a stable, high water level throughout the year. The desired water level will depend on the types of plants grown. With a high climate impact, the water level should preferably stand at approximately 20 cm below soil level all year round. Palus, or paludi, means “marsh” or “swamp” in Latin.

EFFECT

An effect similar to wetlands can be expected, but this has not been scientifically documented.

LOCATION AND ESTABLISHEMENT

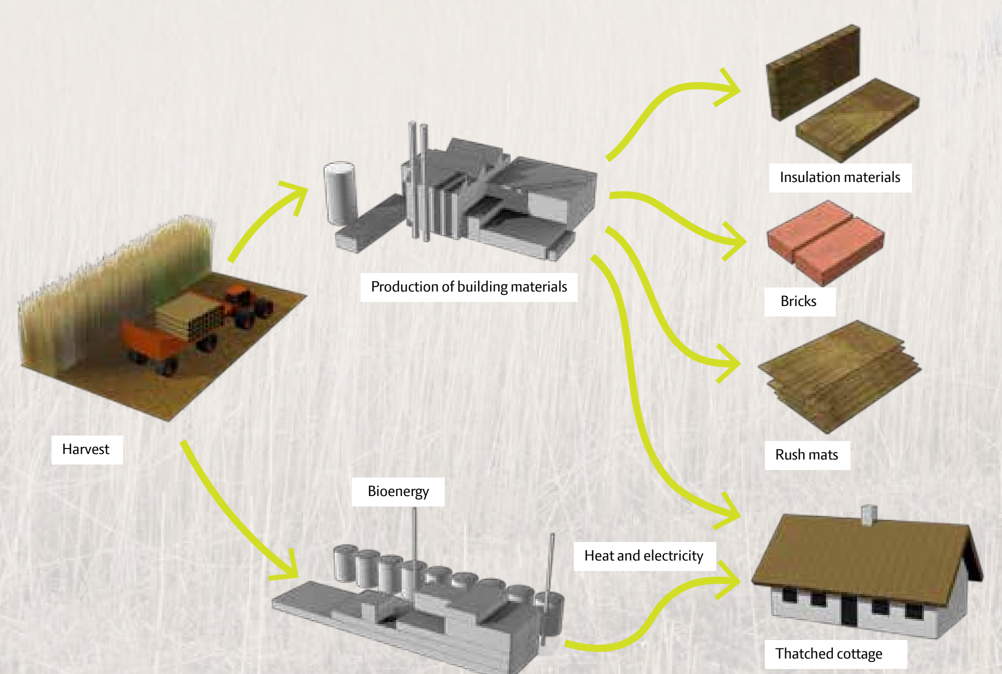
Areals low in terrain and peat soils in agricultural rotation may be obvious to use, but only where it is about to become too wet for traditional farming.

OTHER BENEFITS

Paludiculture provides a habitat for amphibians, birds and small animals and is very likely to increase biodiversity.

COST

Harvesting and establishment costs are currently unknown as the cultivation of wild marsh plants is required. A basic payment is available through growing canary reed grass. The crops can be used for biorefining and biomass for biogas.



Utilisation of paludiculture with reeds and other wild grasses.

Harvesting reeds at Randers Fjord.

DESIGN OF DITCHES

Ditches with blocking ensure a high and stable water level.

PALUDICULTURE

By cultivating crops in paludicultures, lost nutrients can be utilised and returned to the soil. In Germany, grasses from low-lying soil are incinerated in heating plants while in the Netherlands there are attempts to grow feed for cattle. In Denmark, we are looking to use biomass in biogas plants. In the future, marsh crops can perhaps be used for biorefining, building and insulation materials, e.g. materials containing common bulrush do not incinerate well. These methods could help maintain light open areas in meadows where there is a lack of grazing cattle.

Growing common bulrush for cattle feed

At Radboud University in Nijmengen in Holland, scientists are researching crop cultivation in low-land soil. This has both an effect on the climate and the loss of nutrients as the high-water level can prevent climate gas emissions and the crop absorbs nutrients. Research is underway to see whether common bulrush can be used as cattle feed.

Harvesting and use of paludiculture in Holland

Harvesting biomass removes nutrients

Harvesting biomass for biogas at Krogenskær in Brønderslev

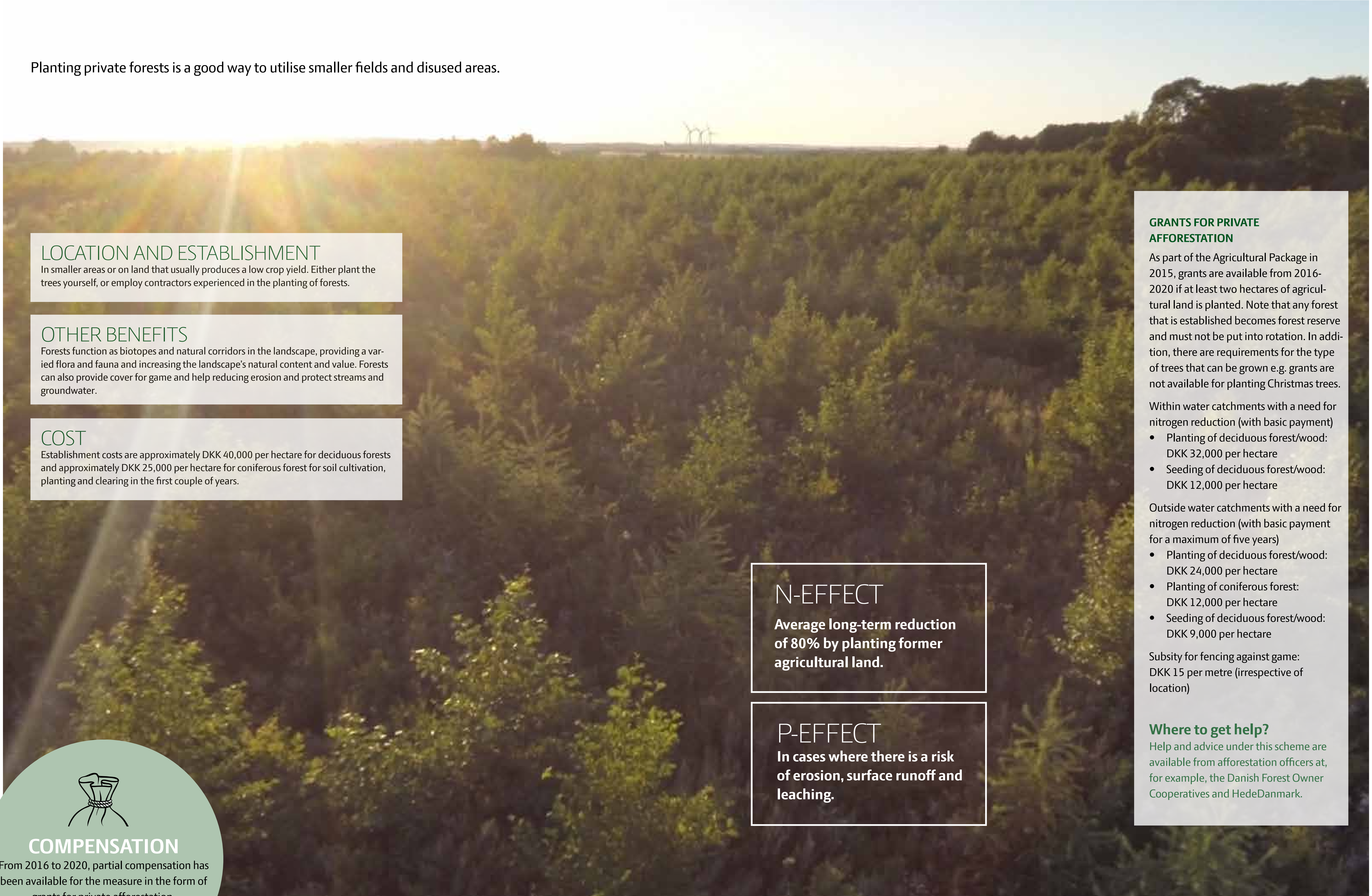
Growing canary reed grass for incineration in Germany

Baling press.

Harvested canary reed grass for incineration.

German heating plant with grass incineration from paludiculture.

PRIVATE AFFORESTATION



Planting private forests is a good way to utilise smaller fields and disused areas.

LOCATION AND ESTABLISHMENT

In smaller areas or on land that usually produces a low crop yield. Either plant the trees yourself, or employ contractors experienced in the planting of forests.

OTHER BENEFITS

Forests function as biotopes and natural corridors in the landscape, providing a varied flora and fauna and increasing the landscape's natural content and value. Forests can also provide cover for game and help reducing erosion and protect streams and groundwater.

COST

Establishment costs are approximately DKK 40,000 per hectare for deciduous forests and approximately DKK 25,000 per hectare for coniferous forest for soil cultivation, planting and clearing in the first couple of years.

N-EFFECT

Average long-term reduction of 80% by planting former agricultural land.

P-EFFECT

In cases where there is a risk of erosion, surface runoff and leaching.

GRANTS FOR PRIVATE AFFORESTATION

As part of the Agricultural Package in 2015, grants are available from 2016-2020 if at least two hectares of agricultural land is planted. Note that any forest that is established becomes forest reserve and must not be put into rotation. In addition, there are requirements for the type of trees that can be grown e.g. grants are not available for planting Christmas trees.

Within water catchments with a need for nitrogen reduction (with basic payment)

- Planting of deciduous forest/wood: DKK 32,000 per hectare
- Seeding of deciduous forest/wood: DKK 12,000 per hectare

Outside water catchments with a need for nitrogen reduction (with basic payment for a maximum of five years)

- Planting of deciduous forest/wood: DKK 24,000 per hectare
- Planting of coniferous forest: DKK 12,000 per hectare
- Seeding of deciduous forest/wood: DKK 9,000 per hectare

Subsity for fencing against game: DKK 15 per metre (irrespective of location)

Where to get help?

Help and advice under this scheme are available from afforestation officers at, for example, the Danish Forest Owner Cooperatives and HedeDanmark.

COMPENSATION

From 2016 to 2020, partial compensation has been available for the measure in the form of grants for private afforestation.

HANDHELD NITRATE MEASURING EQUIPMENT

Nitrogen concentrations in streams and drains can be measured by farmers and consultants with hand-held nitrate measuring equipment. Nitrate measurements can be used in a screening process prior to the siting of drainage measures since the result is immediately displayed in conjunction with a drainage water sample analysed at a laboratory. The nitrate measuring equipment presented in this catalogue is recommended by SEGES.

USE OF MEASURING EQUIPMENT IN DRAINS

To obtain an accurate estimate of the concentration level, measurements must be carried out over the runoff period (the winter half). Note that the mass load of N discharged from the drain further depends on the drainage discharge rate, which vary with high spatial and temporal resolution.

The screening process at a farm or in a small river basin can be carried out in collaboration with an agricultural consultant or catchment officer with knowledge of local conditions. We recommend the following general levels for assessing whether there is potential for a drainage measure (see box).

PHOTO: CAMILLA VESTERGAARD, SEGES

MISUNDERSTANDINGS OF NITRATE MEASUREMENTS

Nitrate concentrations in groundwater are calculated in the unit mg NO_3/l.

Nitrate concentrations in runoff water are calculated in the unit NO_3-N/l.

The difference is that in one method the oxygen atom is taken into account, which means that the permitted upper limit for nitrate in drinking water of 50 mg NO_3/l corresponds to 11.4 mg NO_3-N/l.

Recommended for farmers and advisers

TEST STRIPS

AquaChek test strips can be used to indicate the nitrate concentration level in both streams and drainage water. The test strips are therefore not suitable for measuring precise nitrate concentrations but are useful for screening tasks where the purpose is to determine the level of nitrate concentration in the water. For optimizing results, a mobile app should be used. Deltares: *https://www.deltares.nl/en/software/nitrate-app/* or Danish adopted version: *https://www.seges.tv/video/65134155/nem-metode-til-maling-af-nitrat-i*.

Measurement range:
0-50 mg NO_3-N/l
Price (1 pack of 25 test strips): DKK 160
Seller: Hach Lange Aps

NITRATE SENSOR

The YSI Professional Plus nitrate sensor can be used for the precise measurement of nitrate in drainage water and streams. The sensor with its cable is easily inserted into the water while the value is read on the display. The instrument should be calibrated regularly using calibration fluid.

Measurement range: 0-200 mg NO3-N/l
Price (incl. calibration fluid): DKK 16,220
Seller: MJK Automation Aps

Recommended for advisers

INDICATIVE NITRATE CONCENTRATIONS FOR DRAINAGE MEASURES

NO-GO	0-4 mg NO_3-N/l
MAYBE	4-7 mg NO_3-N/l
GO	≥7 mg NO_3-N/l

TReNDS

The TReNDS research project has contributed knowledge of nitrate measuring equipment.

Test strips are practical for deciding levels of nitrate concentration.

EXPLANATION OF ENVIRONMENTAL EFFECTS

NITROGEN AND ITS VARIOUS FORMS
Nitrogen (N) is an element in the periodic table. The most common form is as the non-reactive odourless and tasteless gas N_2 (dinitrogen, free nitrogen) which makes up approximately 78% of our atmosphere. The most important plant-available nitrogen compounds are ammonium (NH_4^+) and nitrate (NO_3^-).

PLANT AVAILABLE NITROGEN
Plants can only absorb nutrients in ionic form. Both ammonium (NH_4^+) and nitrate (NO_3^-) are ions. Ions work in pairs with other ions with an opposite charge, either in crystal structure (salt) or dissolved in water. Ammonium and nitrate ions are only plant available when dissolved in water. Plants absorb these ions by two different methods according to the ion's charge: positively charged ions (cations) are absorbed by ion exchange while negatively charged ions (anions) are absorbed by a process known as permease.

NITRIFICATION
Most of the nitrogen fertilizer used in Denmark is ammonium fertilizer. However, when ammonium reaches the field, bacteria can use the chemical binding energy in ammonium by converting it into nitrate. Over time, all ammonium will be converted to nitrate in the soil.

SOIL BINDING OF NUTRIENTS
Soil comprises a large number of part-components, the most common being sand, clay, silt and humus. With respect to the retention of nutrients, only clay and humus are interesting in that both are negatively charged. This means that they can retain positively charged ions such as ammonium. Where positively charged ions are bound to soil particles, negatively charged ions occur freely in the soil solution, which means that when the soil water seeps into streams or groundwater, the negatively charged ions will follow to a greater extent than the positively charged ions. Therefore, nitrate is far more likely to wash out than ammonium.

OXYGEN-FREE
Soil typically has a certain amount of oxygen in the upper part of the soil layer. Further down, all pores in the soil will typically be waterlogged, but there can still be oxygen in the water. Much further down, however, there will be no oxygen in the water. This depth, which is known as the redox boundary, varies greatly (2-100m below ground level).

DENITRIFICATION
When organisms are below the redox limit, they can no longer respire (use oxygen to break down substances to generate energy). However, there are some bacteria that can absorb oxygen from oxygenous molecules such as nitrate ((NO_3^-) so they can use the oxygen to break down organic material. The process whereby nitrate is converted to free nitrogen (N_2) by bacteria is known as denitrification. Denitrification is the process that is often required to accelerate the means by which nitrogen is removed from water before it ends up in the marine environment.

PHOSPHORUS AND ITS BINDING CAPACITY
Phosphorus is found in nature as both organic and inorganic phosphate compounds. Phosphate binds to soil particles easily and is retained in most soils unlike nitrate. With neutral pH values, phosphate easily binds to clay minerals. Phosphate can only be absorbed by plants in dissolved inorganic form and can therefore often be the limiting factor in plant growth.

ORGANIC CONTENT OF THE SOIL
Organic matter (O.M.) plays a significant role in crop production and soil health. Building and maintaining a healthy soil that has more O.M. can aid in providing a stronger foundation for higher crop yields and resiliency to environmental stresses. Higher soil O.M. levels often translate into sustainable systems that produce higher, more consistent yields and greater long-term profitability. O.M. enhances the biological diversity and activity in the soil which can increase aggregate stability, water infiltration, and water holding capacity. O.M. is a valuable nutrient source for plants and living organisms.

SEDIMENTATION
When water is moving, it can carry many different types and sizes of particles, such as sand and clay. But when water is stagnant, all particles heavier than water will sink to the bottom sooner or later. This effect is called sedimentation. Phosphorus and other nutrients are often bound to particles, which is why they can be removed from the water by sedimentation.

oplands
konsulenterne

Contact your catchment officer and learn more about:

Mini-wetlands
Mini-wetlands are effective filters in the landscape that clean drainage water of nitrogen and phosphorus. If you are considering establishing a mini-wetland, a catchment officer will be able to help you with the following free of charge:

- A review of your options for initiating a grant-funded project;
- Preparation of tender documentation;
- Procuring offers from contractors;
- Help to obtain the necessary permits and approvals from the authorities;
- Preparation of grant applications;
- Coordination of project implementation;
- Final reporting and request for payment.

Wetlands
Wetlands have beneficial and safe effects on environment and nature, and it can be financially prudent to participate in a largescale wetland project. If you are considering a wetland project, a catchment officer will be able to assist you with the following:

- Clarification of your options for embarking on a wetland project;
- An overview of the financial consequences of participating in a project;
- A review of what the wetland area might look like;
- Contact with the municipality which will be able to apply for grants and implement the project

Afforestation
Planting private forest is a good opportunity to utilise smaller fields and disused land. Afforestation enables the practice of forestry over the long term. Private afforestation helps to reduce nitrogen emission.

If you are considering afforestation, a catchment officer will be able to help you explore your options for obtaining grants for the project. Afterwards, you should contact a consultant or contractor to help you with grants and planning.

READ MORE AT
www.oplandskonsulenterne.dk

VIEW FILM
The catchment process for mini wetlands

Innovationsfonden

TReNDS

STØTTET AF
promilleafgiftsfonden
for landbrug

Danish Agriculture & Food Council F.m.b.A.
SEGES
Agro Food Park 15, DK 8200 Aarhus N

+45 8740 5000
info@seges.dk
seges.dk

SEGES