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RAISED BOG REGENERATION AFTER PEAT HARVESTING IN NORTH-WEST GERMANY

Kohosoiden luonnontilaan palauttaminen turpeen noston jälkeen Luoteis-Saksassa

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An increasing awareness of the environment and the wide extension of mined peatlands require actions and measurements in order to ensure their regeneration and protection. A brief description of the most important peat harvesting methods in North-West Germany shows the stratigraphy of peatlands after exploitation has been finished and ecotechnological actions have been started to initiate a raised bog regeneration. The actions and measurements applied depend also on the properties of the peat as on the properties of the top spit layer. The requirements for a successful rewetting of peatlands will be shown. The terminology concerning the subject of raised bog regeneration will be explained.

Keywords: nature protection, peatlands, rehabilitation, top spit

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INTRODUCTION

Plinius the Elder (23/24–79 AD.) was the first to report on the extraction of peat as a source of fuel. However, not until the end of the 16th century were raised bogs used extensively by Dutch-inspired Veen-cultivation alongside peatland burning (Overbeck 1975). At the beginning of the 20th century peatland burning was replaced by the German raised bog cultivation (*Deutsche Hochmoorkultur*) (Brüne 1948, Baden 1952). As a consequence of intensified farming and harvesting of peat since the middle of the century the wide raised bogs in the North-West of Germany were extensively drained to considerable depths. They degenerated and became heathlands in which peat accumulation ceased.

Although C.A. Weber already in 1901 realised the value of raised bogs in Germany and demanded actions for their protection, the first steps of peatland protection instead of peatland utilisation did not take place until the beginning of the 1970's (Kuntze 1973, Eggelsmann 1975, Müller 1975, Tüxen 1976, Ringler 1977).

An area of 330 000 ha in Lower–Saxony was originally covered by raised bogs. Nowadays there are no more than 250 000 ha. Although there isn't any complete, intact and untouched peatland within these (Schmatzler 1982), there is an area of 28 120 ha that is valuable for nature protection without any peat mining. This area contains parts of almost undisturbed marginal zones of peatlands.

A second area with a total of 25 580 ha is designed for nature protection. This area consists of parts with heathland vegetation, caused by former drainage, parts of manual peat cutting with alteration of wet and dry locations and cultivated raised bogs (grassland).

Thirdly, due to the peatland protection-programme, another 32 550 ha are considered suitable for raised bog regeneration after peat harvest (Birkholz et al. 1980, Ministry of Nutrition...1981, Schmatzler 1991).

The first field trial, concerning the raised bog regeneration has started in 1976 in Lichtenmoor, Landkreis Nienburg (Kuntze & Eggelsmann 1981, Eggelsmann & Klose 1982, Blankenburg & Kuntze 1987, Blankenburg & Eggelsmann 1990, Schwaar 1991). In the meanwhile there have been constructed many new trials on industrial cutted and also on non-mechanical cutted sites. In 1990 already 5436 ha of harvested peatlands were rewetted, 70% of these are already protected areas according to the law of nature protection (Blankenburg & Schmatzler 1991).

The following paper is a survey of the most important facts about the regeneration process of peatlands in North-West Germany, according to the results that have been published so far.

PEAT MINING

Peatland stratigraphy before peat mining

A typical stratigraphy of a raised bog in North-West Germany before peat cutting is characterised by an underlying mineral layer (mostly sand with an almost impermeable ortstein) or a minerotrophic peat layer. The peat layer this above consisting of black peat shows a high degree of decomposition (7–10 v. Post). White peat, the next layer, is decomposed to a lesser extent (1–6 v. Post). The surface layer can be defined as a pedogenetic influenced horizon layer of drained raised bogs with heathland vegetation (Fig. 1) (Roderfeld 1992). Its soil formation is caused by natural and anthropogenic changes of water level with increasing mineralization and decay. In principle this surface layer, named top spit, is not valuable in terms of peat harvesting and so it is stored in the cutting ditches during peat harvesting.

Unless milled peat is extracted, the surface layer is just as valuable as the peat itself. For technological condition there is no need for the storage of top spit material only in view of regeneration process.

A short description of the most important peat mining techniques shows the differences of peat stratigraphy in the beginning of regeneration actions.

White peat mining (sod-cut-method)

When applying the sod-cut-method in white peat mining, the top spit layer is stored in the cutting ditches during mining (Fig. 2). Generally 10–15 years are needed to cut peat to a depth of 1 m. Because *Molinia coerulea* and some other plants are able to colonise the peat surface in a short time, the surface sod of the next cutting process is added to the top spit material. This causes the top spit to become more and more enriched by white, slightly decomposed peat.

Black peat mining

Generally white peat cutting is followed by black peat mining. At the bottom there is a valuable black peat layer covered by a 30 cm thick top spit layer. The peat is usually mined with a bucket ladder and it is put onto the top spit by a spreading equipment for outdrying or freezing (Fig. 3). This method leads to an enrichment of top spit with highly decomposed peat crumbs.

Milled peat

Nowadays, in regions with favourable climatic conditions the technique of mining milled peat is preferred. Using this method of extraction, it is possible to harvest the top spit layer as a valuable raw material. However, due to the requirements of law, top spit material has to be preserved for the rewetting (Ministry of Nutrition...1988). In order to solve the technical problem of top spit storage (a thickness of 30 cm corresponds with a volume of 3000 m^3/ha), it is suggested to keep the top spit on a neighbouring field during milled peat winning

(Fig. 4) (Eigner & Schmatzler 1991). Later it is removed to the cut-over-site.

The cost is quite considerable in comparison to the other methods of exploitation.

RAISED BOG REGENERATION

Climatic conditions

A prerequisite for a successful rewetting is a positive climatic-water-balance (cbw), which is achieved in North-West Germany. While there is a negative cbw during summer month, there is a positive cbw during winter time. Excess water can be stored in the remaining peat layers and is used for colonising plants in the dry summer months. An average annual precipitation of 750 mm and an evaporation of 550 mm cause an annual water run off of 200 mm (Eggelsmann 1981).

Phases of raised bog regeneration

The aim of raised bog regeneration in North-West Germany is the re-establishment of the original, peat accumulating raised bog vegetation, respectively the class of Oxycocco-Sphagnetea and Scheuchzerietea (Tüxen 1976). Joosten (1992) defines bog regeneration as the process of renewed development towards a bog after natural or cultural disturbance of bog.

The following stages belong to the development of raised bog regeneration (Kuntze & Eggelsmann 1981) (Fig. 5).

The degeneration phase of the cut-over-area will be finished after its rewetting, the initial stage of regeneration. The indication of a successful rewetting is a permanent rise of water level almost up to the surface as a result of suitable ecotechnical actions.

Rewetting is proved by the first surface run off, which can be expected after a period of 3–5 years (short-term) (Eggelsmann & Klose 1982, Blankenburg & Eggelsmann 1990).

After rewetting the phase of degeneration will be passed to the phase of stagnation. At that period the mire will neither degenerate nor grow.

The following stage of renaturation is characterised by the colonisation of plants and animals, adapted to the mires. It is suspected that several decades are needed to reach the stage of renaturation.

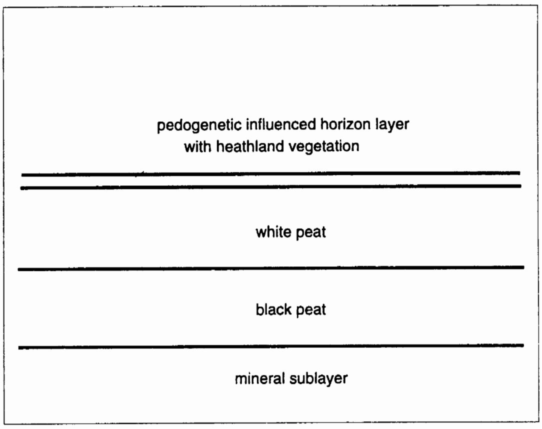

Fig. 1. Typical stratigraphy of a drained raised bog in North-West Germany before peat mining.

Kuva 1. Tyypillinen luoteissaksalaisen ojitetun kohosuon turvestratigrafia ennen turpeen noston aloittamista. Kivennäismaan päällä on maatuneen tumman turpeen kerros. Tätä seuraa vaaleampi raaempi turve, jonka päällä on varpukasvillisuutta.

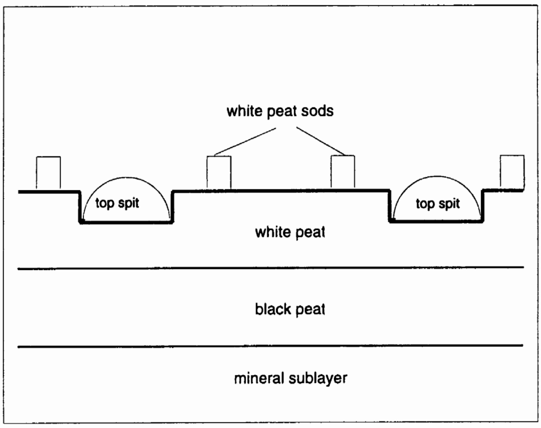

Fig. 2. Top spit storage during white peat cutting (sod-cut-method).

Kuva 2. Pintakerroksen (top spit) varastointimenetelmä nostettaessa vähän maatunutta vaaleaa pintaturvetta.

The last phase, the regeneration; indicated by peat-accumulation and regrowth, provided that it happens; will probably take some centuries.

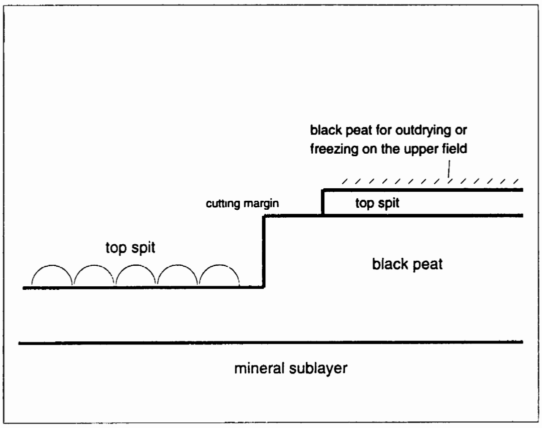

Fig. 3. Top spit storage during black peat mining (bucket ladder method).

Kuva 3. Pintakerroksen varastointimenetelmä nostettaessa hyvin maatunutta tummaa pohjaturvetta.

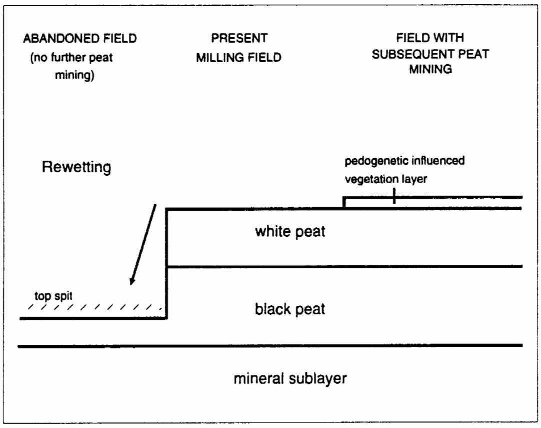

Fig. 4. Top spit treatment during milled peat mining.

Kuva 4. Pintakerroksen käsittelymenetelmä jyrsinturvekentällä. Pintakerros (vähintään 30 cm) levitetään takaisin hylätylle turvekentälle, jonne on jätetty vähintään 50 cm:n paksuinen hyvin maatunut pohjaturvekerros.

Ecotechnological actions and measurements

In order to receive a permanent water level near the surface, the ditches first need to be blocked and sealed; peat embankments have to be constructed and the surface has to be levelled. These measurements are responsible for the prevention of rainwater run off (above ground and below ground).

While a virgin raised bog has a downward annual seepage of 36 mm, it is shown by Blankenburg & Kuntze (1987) and Schouwenaars (1988) that the cut-over-sites have a higher seepage up to 102 mm.

If there are ditches that reach the mineral subsoil, the problem of minimising the water run off arises. In percolation experiments Schäfer et al. (1987) made investigations about the permeability of different materials. The results show, that the highest reduction of seepage is achieved when the ditches are sealed with a black peat suspension that leads to a self sealing process. These results are already part of the law regulations concerning the technical management of cut over raised bogs (Ministry of Nutrition...1988).

The extent of surface-levelling depends on the topography. If the surface slope is higher than 1%, it is useful to build up a cascade polder landscape similar to what is used for rice farming. The dams of peat need well-built overflow installations to guarantee the harmless drainage of rain surplus and to prevent water erosion (Eggelsmann 1987, 1988).

A micro relief of artificial hummocks and hollows with level differences of 30 cm, set up by a plough, can be advantageous for the colonisation of plants especially *Sphagnum* ssp. (Blankenburg & Eggelsmann 1990, Schwaar 1991).

In the Netherlands, a model concerning the hydrology of raised bogs has been developed for some years. By means of this model SWAMP (Simulation Water Management in Peatlands), it is possible to simulate the water balance of rewetted raised bogs and to calculate the downward seepage and the vertical hydraulic saturated conductivity. On the basis of this data the effects of hydrological conditions on the water level can be determined, thus the most suitable ecotechnological measurements can be chosen (Schouwenaars 1988).

Exact data of discharge, groundwater fluctuation and actual evapotranspiration is needed for its application (Schouwenaars et al. 1992). By testing this model in three well-known field trials in the Netherlands and North-West Germany its evidence was pointed out. The calculation of water level satisfactorily corresponds with the results of measurements (Schouwenaars et al. 1992).

Hydrological buffer zones

Analogous to Hooghoudt's formula, concerning the drainage distance, Eggelsmann (1977, 1982) developed a formula to calculate the width of hydrological buffer zones for bog regeneration areas.

(1) The protected area itself: It has to be protected against all influences as strictly as possible.
(2) The aim of the second buffer zone is the hydrological protection of the first zone. Its size can be calculated, if the lowering of water level within the area does not differ more than 0.8 and 1.5 m and if the permeability of the peat layer is known. Several field investigations in North-West Germany have shown that the width of this hydrological zone has to be 30–80 m in raised bogs with a thick layer of peat (> 2m) and 120–150 m in raised bogs with a thin layer of peat above fine sand.
(3) The third zone is the transitional zone that touches area under human influence (urbanism, agriculture, forestry). Depending on the circumstances it must have a variable size from 500 m to > 2 000 m (Eggelsmann 1990).

If the difference between the water level of the main discharge channel and the highest point of surface within the protected zone is bigger than the Eggelsmann-formula demands, and the surface slope within the zone is large, the formula is no longer valuable. In this case another formula, developed by Van Molen (1981), has to be applied to get reasonable zone sizes. Aue (1991) proved this by investigating the hydrological function of a man-made marginal slope in a raised bog in the North of Germany (Dosenmoor, Schleswig–Holstein).

Function of the black peat layer

From the hydrological point of view a virgin raised bog is characterised by an almost impermeable underlying layer and by a surface layer (mire vegetation) with an extremely high water storage capacity. This results in a water level amplitude of maximum 20–30 cm (Baden & Eggelsmann 1964).

In order to get analogous conditions, one of the important facts for the rewetting of cut-over peatlands is the hydrological condition of the black peat layer and the surface layer (top spit). The function of the black peat layer is rain water retention and the seepage reduction.

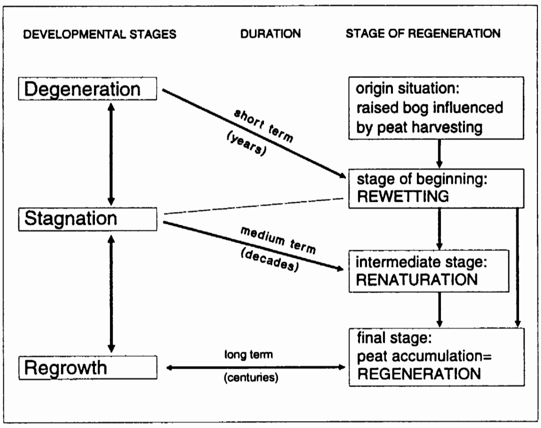

Fig. 5. Possible stages of raised bog regeneration.

Kuva 5. Kohosuon mahdollisia vaiheita palautettaessa alueita luonnontilaan. Ensimmäinen vaihe on alueen vettäminen, jonka jälkeen muutaman vuoden kuluttua tapahtuu alueen biologisen luonteen palautuminen. Soiden uudiskasvuun vaaditaan kymmenien tai satojen vuosien aikajakso.

The hydrological function of the black peat is complete, when its thickness is not less than 50 cm, its peat highly decomposed and its permeability low ($<10^{-9}$ m/s) (Blankenburg & Kuntze 1987, 1988).

Function of the top spit layer

Nowadays the need of a water storing peat layer, i.e. the highly decomposed black peat layer, is generally acknowledged.

According to numerous authors both the 30 cm thick top spit layer and the black peat layer are necessary for the regeneration process (Kuntze 1973, Pfadenhauer & Kinberger 1985, Nick 1986, Eggelsmann & Blankenburg 1989, Ringler 1989, Blankenburg & Eggelsmann 1990, Klötzli 1990). The main functions of the top spit layer are:

1. Protection of the water storage layer from evaporation; this leads to small water fluctuations and permanently high water level near the surface.

2. Additional water storage,
3. Microbiological, chemical and physical properties, which ensure the germination of pioneer plants and typical mire vegetation.

It is of utmost importance that top spit material has the property of minimising the fluctuation of water level. Otherwise the decreasing water level reaches the highly decomposed peat layer during dry periods. Shrinkage cracks would occur causing an increasing downwards seepage. If the cracks reached the mineral soil and their shrinkage was irreversible, as in highly decomposed peats (Ilnicki 1967); the property of water storage would be lost. New technological actions for a successful rewetting process would then be necessary.

The hydrological function of top spit, the prevention of evaporation from the black peat, strongly depends on its proportion of large pores (= pores size > 50 µm). The top spit reduces the amplitude of water table fluctuations to a reasonable size of 30-40 cm, if its proportion of large pores is >20% and its thickness is >30 cm. When considering the relationship between the degree of decomposition and the proportion of large pores of peat (AG Bodenkunde 1982) and investigations of top spit material in field trials (Eggelsmann & Blankenburg 1989, Blankenburg 1991), the top spit should not be decomposed to more than a medium extent. Highly decomposed top spit is unable to fulfil the required hydrological functions (Roderfeld 1992).

In consideration of the different peat extraction methods, it is evident that the rewetting of sites, where black peat mining was practised during long periods, is more difficult and takes more time than rewetting of sites, where white peat mining (sod method) took place.

A further problem for a successful rewetting process is the possible occurrence of water areas on the surface. With increasing proportion of macro pores the saturated water conductivity rises and therefore the rate of infiltration also rises (AG Bodenkunde 1982). A large capability of infiltration diminishes the possibility of surface water development. Surface water would both increase the evaporation and probably the eutrophication caused by water birds.

Field investigations have shown that the problem of surface water, which appeared in the Leegmoor trial, did not occur in the Lichtenmoor trial. This was caused by the degree of decomposition of top spit, which was higher in the Leegmoor than in Lichtenmoor (Blankenburg 1991).

The second function of the top spit layer, i.e. an additional water storage, can be achieved if it is kept under wet conditions during peat mining and if it is not decomposed to a high extent (Roderfeld 1992). The exact data of decomposition to a low, medium and large extent are given in Table 1.

The third function required of top spit was examined with pot experiments (*Eriophorum vaginatum, Erica tetralix, Molinia coerulea*) and microbiological measurements (Roderfeld et al. 1993). The quality and quantity of plant growth was connected with the microbiological activity of samples. Neither on black peat nor on white

method, *menetelmä*	Degree of decomposition, *maatumisaste* slight, *alhainen*	medium, *keskinkertainen*	high, *korkea*
r-value (%) (DIN 11540, 1989)	< 51.0	51.0–59.7	> 59.7
k-value (DIN 11540, 1989)	< 0.92	0.9–1.19	> 1.19
Remission (%) (Jacob 1958, 1967)	> 20.4	17.9–20.4	< 17.9
D-Value (Davidyk 1987)	< 16.8	16.8–23.5	> 23.5
Humification (V. Post)	< 3	3–4	> 4

Tab. 1: Classification of top spit's degree of decomposition.

Taulukko 1. Pintakerroksen luokittelu maatuneisuuden perusteella.

peat did the plants grow well. This similar low growth was achieved on highly decomposed top spit. Better results were received on slightly decomposed top spit, the best on medium decomposed top spit.

The less decomposed the top spit was the higher was the probability towards a regeneration. Concerning top spit quality the sod cut method can be considered as the best one while on fields, where black peat was mined, the rewetting will take more time.

Milled peat fields occupy huge areas at the same time and the top spit can not be stored under favourable conditions. Usually they are without any vegetation and the recolonisation of mire plants will be very difficult.

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TIIVISTELMÄ:

KOHOSOIDEN LUONNONTILAAN PALAUTTAMINEN TURPEEN NOSTON JÄLKEEN LUOTEIS-SAKSASSA

Ihmisen toimesta muuttuneiden kohosoiden suuri määrä Luoteis-Saksassa sekä lisääntyvä kansalaisten huoli ympäristönsuojelusta vaativat nykyisin soiden suojelua sekä häiriintyneiden suoekosysteemien palauttamista luonnontilaan. Turpeen noston jälkeiset soiden entisöintitutkimukset alkoivat alueella jo 1970-luvun alussa. Tällöin ruvettiin etsimään vastauksia seuraaviin kysymyksiin:

- Millä tavoin päästään parhaaseen tulokseen alueen vettämisessä, joka on suon entisöinnin ensimmäinen vaihe?
- Mitä ekoteknisiä toimenpiteitä on suoritettava vettämisen onnistumiseksi?

Vettämisen jälkeen tapahtuu tyypillisten suolajien ilmestyminen (kolonisaatio) paikalle. Tätä voidaan kuvata soiden entisöinnin toiseksi vaiheeksi eli suon biologisen toiminnan palautumiseksi (renaturaatio). Viimeisenä vaiheena tulisi olla soiden uudiskasvu (regeneraatio), jolloin suoekosysteemi muodostaa turvetta.

Artikkelissa kuvataan tärkeimmät Saksassa käytettävät turpeennostomenetelmät, koska ne määräävät turvekerrosten stratigrafian vettämisen alkaessa. Ekotekniset toimenpiteet on suunniteltava siten, että vedenpinnan taso on jatkuvasti lähellä suon pintaa. Suolajien leviämisen helpottamiseksi saattaa joissakin tapauksissa olla edullista rakentaa keinotekoisesti mättäitä ja kuljuja. Paitsi positiivisen vesitaseen, entisöitävä suoalue vaatii myös hydrologisen suojavyöhykkeen, jonka koko voidaan laskea.

Saksassa täytyy suon pintakerros kasveineen (*top spit, Bunkerde*) säilyttää viereisillä saroilla tai ojissa turpeen noston ajan. Entisöinnin alkaessa täytyy jäävän vettä läpäisemättömän pohjaturvekerroksen olla paksuudeltaan vähintään 50 cm. Tämä peitetään n. 30 cm paksulla pintakerroksella, jonka tulisi maatuneisuudeltaan olla keskimaatunutta parhaan entisöintituloksen saavuttamiseksi.

Tulokset kenttäkokeista osoittavat, että suotuisissa oloissa onnistunut vettämisvaihe kestää 3-5 vuotta. Näin ollen suon biologisen toiminnan palautumisen vaihe on jo alkanut joissakin kohteissa. Huolimatta saavutetuista hyvistä tuloksista, laskeuman mukana kulkeutuvat ilmansaasteet sekä oletettu ilmaston muutos voivat vaikuttaa entisöitäviin soihin vielä tuntemattomilla tavoilla.

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