POSSIBLE EFFECTS OF GROUND WATER LOWERING ON SOME PEAT SOILS IN SJÆLLAND

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In four peatlands in the central part of Zealand nine profiles have been investigated to estimate the effect of a lowering of the groundwater level.

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INTRODUCTION

In Denmark peat soils usually occur as rather small areas in depressions with a high ground water table. The formation of the peat is dependant on the high water level and if this is lowered the peat formation stops and the peat already formed starts to decompose. Many peat soils have been reclaimed for agricultural purposes through lowering of the water table by means of artificial drainage systems. However, a lowering of the water level may also take place due to pumping of water for water supply systems or other purposes.

In their natural condition peat soils have a characteristic flora and fauna which is dependant on the high water level and the properties of the peat. A lowering of the water table causes changes in the properties of the peat, and it will therefore affect the flora and fauna both directly and indirectly.

The study described in this paper was made in order to estimate the possible effects of a reduced ground water level on the properties of some peat lands situated within a potential water pumping area in Southern-Sjælland.

A lowering of the water table causes subsidence of the peat. A rapid subsidence occurs immediately after the water lowering, simply because water accounts for a large share of the volume of the peat. A partial removal of this water will cause a considerable shrinking of the peat. The water removal also causes a reduced buoyancy which increases the subsidence. A slower subsidence, which is due to oxidation of the peat, will also take place because oxygen gets access to the peat layers upon removal of the water.

The extent of subsidence depends, of course, on the thickness of the peat layers as well as on some physical and chemical properties of the peat as described by Kuntze (1976). Uhden (1966) found that a subsidence of 60-90 cm had occured during 50 years in a sphagnum peat in Northern Germany. The total thickness of the peat was about 4 m and tile drains had been installed at 150 cm depth. The subsidence mainly took place in the layer above the drains.

In peatlands near Bydgoszcz in Poland Ilnicki (1972) found a yearly subsidence of 0,5-1,2 cm depending on the depth of the drainage ditches. The ditching of the peat lands was started 100-200 years ago, but the most profound drainage was carried out about the year 1900.

Sorteberg (1975) reported a subsidence of 14-137 cm in 15 Norwegian peat localities during 13-19 years after ditching. The thickness of the peat varied from less than 1 m to about 3,5 m and the subsidence increased with the thickness of the peat.

In a Karelian peat area Nesterenko (1976) found a subsidence of 38 cm during 2 years following installation of a closed drainage system. During the subsequent 10 years the subsidence decreases to 1,35 cm pr year. The total thickness of the peat layers was 2-2,5 m.

In three peat areas in the Netherlands, Schothorst (1977) found that a subsidence of 6-10 cm took place during 6 years following ditching. The subsidence increased with increasing depth of the ditches. 65% of the subsidence was attributed to shrinking and oxidation of the peat above the ground water level while the rest was due to compression of the lower peat layers.

In warmer climates substantially higher rates of subsidence may occur. In the Florida Everglades, Stephens (1956) found a yearly subsidence averaging 3 cm since the land was drained in 1914. According to Levin and Shoham (1972) a yearly subsidence of 10 cm has taken place during 12 years following reclamation of some areas with thick peat layers in Israel.

Water removal not only causes subsidence but also changes in other physical and chemical properties of the peat. Of particular importance is the mobilization of plant nutrients contained in the peat since this alters the nutrient status of the peat land and hence affects its flora. The most important plant nutrient in this respect is nitrogen which is present in large amounts in some peats. During the oxidation of the peat, which takes place after lowering of the water table, the nitrogen is mobilized as nitrate which can be used immediately by the plants.

Other nutrients may also be mobilized and become available to plants. The extent of this mobilization depends, however, strongly on the nature of the peat. Some peats, e.g. spaghnum peat, are very low in these plant nutrients while peat developed under eutrophic conditions may have a high nutrient content.

PEAT LAND INVESTIGATED

All the peat areas investigated are situated within the catchment area of the Suså river in Southern Sjælland. The geology of the area is investigated and described by Milthers (1908) and Andersen (1931). The surface is dominated by moraines of varying thickness but other glacial formations such as tunnel valleys, eskers etc. are also present. Some of the peat lands investigated are situated in depressions with deposits from glacial lakes. The depressions are separated by moraine ridges mainly having an east-west direction. The glacial lake deposits are formed at the end of the Weichsel glaciation and they have a high clay content. In some areas the deposition of clayey material has continued after the deglaciation and subsequently peat has formed on top of the inorganic sediments. In this way most of the peat lands investigated are thought to be formed.

Øllemose (UTM 32UPG853398) is about 7 ha. It is developed in an almost circular depression in a moraine landscape and it is drained through Vendebæk and Lilleå to Suså. The peat thickness varies from 0,6 to 1,6 m. In the eastern part rather sandy, well sorted materials are found under the peat while the materials in the central and western parts are more clayey but also well sorted. The central part of the bog has been excavated for fuel production. The vegetation is rich in species with a clear zonation according to wetness. The surface along a line with direction east-west is shown in Fig. 1.

Gammellung (UTM 32UPG808334) has 0,3 to 1,5 m thick peat layers developed on bog lime or sandy materials. The peat has to a large extent been excavated for fuel production. In the central part where the investigated profile is located the peat has been almost completely removed, and bog lime is present near the surface. Gammellung is drained through Svalebæk to Suså.

Kirkelyng (UTM 32UPG765335) has a spaghnum peat developed on top of a low moor peat. The thickness of the organic layers varies and has probably exceeded 2 m in the deepest parts, but over large areas 1-2 m has been excavated for fuel. Layers consisting of organic-lacustrine sediments (gyttje) are found under the peat layers. Their deeper parts contain lime and shells. Thick layers of clay with a content of calcium carbonate are present under the gyttje. The bog is drained by Torpe canal.

Kroglyng (UTM 32UPG778333) is situated near Kirkelyng and is in many respects similar to this. The same sequence of sphagnum peat, low moor peat and gyttje is found, and the thickness of the organic layers varies from 0,2 to 2,5 m but also in this bog large areas have been excavated. Like in Kirkelyng, clay is found under the gyttje. In the investigated profile neither the peat nor the clay contain calcium carbonate. The bog is drained to Suså through a canal.

PROFILE SITES

9 profiles have been investigated: 5 in Øllemose, 1 in Gammellung, 2 in Kirkelyng and 1 in Kroglyng.

In Øllemose profiles 1 and 5 are placed in areas at relatively high altitude with rather thin peat layers near the edge of the bog. The vegetation at the site of profile 1 is dominated by Cirsium palustre, Deschampsia caespitosa, Filipendula ulmaria and Galium aparine. The vegetation at profile 5 is rich in species comprising Cirsium arvense, Angelica silvestris, Filipendula ulmaria and Agropyrum repens. Profile 2 is also places at a relatively high altitude. The vegetation is dominated by Glyceria maxima and Deschampsia caespitosa. Profile 3 is placed in the central part where the bog is expected to have its maximum depth but the upper peat layers have been removed by excavation. The vegetation is exclusively Typha latifolia. Profile 4 is also situated in the central part where the peat layers are thick and at this site no excavation seems to have taken place. The vegetation is almost entirely Deschampsia caespitosa.

In Kirkelyng both profiles are placed where the bog is rather deep. Profile 1 is at a lower altitude than profile 2 because the upper peat layers have been removed by excavation at the site of profile 1. The vegetation at profile 1 includes Calamagrostis canencens, Eriophorum angustifolium, Epilobium palustre and Lycopus eurepaeus. At profile 2 there is a tree and shrub vegetation, mainly Betula. The low vegetation is dominated by Calluna vulgaris, Molinia coerulea and Erica tetralix. Sphagnum is also present.

The profiles in Gammellung and Kroglyng are also placed in the deepest parts. At the Kroglyng profile site the vegetation is similar to that found at profile 2 in Kirkelyng with the exception that Erica tetralix does not seem to be present. At the Gammellung profile a tree vegetation, mainly Betula, is present. The herb flora is rich in species including Peucedanum palustre, Eupatorium cannabium, Deschampsia caespitosa and other grasses.

METHODS

Profile descriptions were made in holes transversing all the organic layers and extending into the mineral layers below the peat. The descriptions were made mainly according to the guidelines given in Soil Survey Manual (1951), and the horizon symbols used are those defined in Soil Taxonomy (1975). The colour is evaluated according to Munsell Soil Color Charts (1954) on wet soil.

Water content and bulk density were measured on undisturbed samples collected from selected peat layers in stainless steel rings having af volume of 39,3 cm^3. In the laboratory the samples were partly trimmed and saturated with water by standing for 24 hours in a basin with a water level equal to half of the ring height. Then the samples were trimmed so that the volume of the saturated soil was exactly that of the rings. By this technique the physical parameters mentioned below are based on the volume of the soil at zero tension (the tension of a free water surface). The water content of the trimmed samples was determined by drying at 105°C for 24 hours. From this the water content, on weight and volume basis, as well as the wet and dry bulk density were calculated.

The drying caused a considerable shrinking of most samples. To obtain a rough estimate of this shrinking the dried samples were submerged under water in a measuring cylinder and the volume increase was read immediately. This procedure is applicable only because the dry peat samples absorb water rather slowly.

Sampling and pretreatment for chemical and mechanical analysis. Samples for these analyses were collected as disturbed samples from each layer during the profile description. They were transported to the laboratory in PVC-bags. After air-drying they were ground in a mortar or a power mill. Samples to be used for mechanical analyses were of course treated cautiously to avoid any disintegration of the grains.

pH-measurements were made on samples suspended in water and 0.01 M $CaCl^2$. For both liquids a soil-liquid ratio of 1:2,5 was used. In a few cases it was necessary to increase the amount of liquid because the soil absorbed it so strongly that measurements could not be made using the ratio specified above. However, this is not assumed to have had any significant effect on the results. The measurements were made with a Radiometer pH-meter equipped with glass and calomel electrode.

Organic carbon determination was made by means of a Leco furnace as described by Tabatabai and Bremner (1970). The carbon dioxide evolved by combusion of the sample was absorbed on ascarite (asbestos impregnated with sodium hydroxide) and measured by weighing. A correction for carbon dioxide originating from calcium carbonate was derived from the results of the carbonate determinations decribed below. This is possible because carbon dioxide from calcium carbonate is evolved quantitatively at the high temperature where the combustion is made.

Nitrogen was determined by the Kjeldahl procedure described by Kjær (1968).

Carbonate was determined using Scheibler's apparatur as described by Kjær (1968).

Texture was determined on samples from all mineral horizons using the combined sieve and pipette method described by Kjær (1968). Prior to the analysis calcium carbonate and organic matter were removed by treatment with an acetate buffer and hydrogen peroxide respectively. These procedures are described by Møberg (1976). The textural class names are given according to Soil Survey Manual (1951).

Adsorbed cations were determined by 3 successive treatments with 1 M ammonium acetate at pH 7 as described by Jackson (1958). In the extracts sodium and potassium were determined by flame emission spectrophotometry while calcium and magnesium were determined by atomic absorption spectrophotometry. An estimate of the exchangeable acidity was obtained by titration of an aliquot of the extracts with 0,5 N NaOH. The titration was made by means of a pH-meter and the end-point was pH 7. The results are to be regarded only as approximations to the exchangeable acidity at pH 7. More accurate values may be obtained by more elaborate methods but the approximate values obtained were considered satisfactory for the present study. The cation exchange capacity was taken as the sum of the exchangeable cations (including acidity). The values were also used for calculation of the base saturation percentage. In samples containing calcium carbonate the content of exchangeable calcium cannot be determined because the ammonium acetate dissolves calcium from the calcium carbonate. Accordingly the cation exchange capacity and the base saturation percentage cannot be calculated, but the latter will formally be above 100 since the cation exchange is determined at pH 7.

Levelling of Øllemose was made along a line with direction east-west. The concrete footing of a house was used as bench mark.

Ground water level was measured in iron tubes bored in the solid mineral soil below the bogs. The tubes are perforated with 2 mm holes for each 10-15 cm. Since the surface of the peat layers are known relative to the top of the iron tubes these may be used together with the levelling for future subsidence measurements.

RESULTS

Profile Descriptions

Øllemose profile 1

Oi 0-5 cm.	undecomposed plant residues
Oe 5-33 cm.	Black (5 YR 2/1), partly decomposed organic material, moderate very coarse prismatic and moderate fine granular structure, plastic, non-sticky, abrupt smooth boundary to

Oa 33-76 cm. Black (5 YR 2/1), well-decomposed organic material, granular structure, plastic, non-sticky, abrupt wavy boundary to

Cl 76-90 cm. Dark grey (10 YR 4/1), sandy loam with small content of calcium carbonate, few dark red mottles, weak granular structure, slightly plastic, non-sticky, abrupt wavy boundary to

C2 90-107 cm. Grey (10 YR 5/1), sandy loam with calcium carbonate, partly as shells, practically without structural aggregates, non-plastic, non-sticky. Abrupt smooth boundary to

C3 107 cm. Grey (10 YR 5/1) loam with calcium carbonate, layered (clayey layers alternate with more sandy ones), weak platy structures, plastic, non-sticky.

Øllemose profile 2

Oal 0-48 cm. Black (5 YR 2/1), well-decomposed organic material, moderate medium granular structure, plastic, slightly sticky, clear wavy boundary to

Oa2 48-72 cm. Very dark greyish brown (10 YR 3/2) well-decomposed organic material, weak platy structure, plastic, nonsticky, abrupt irregular boundary to

C 72- cm. Dark grey to olive grey (5 Y 4/1,5) loam with a few thin sandy layers, weak coarse angular blocky structure, very plastic, sligthly sticky.

Øllemose profile 3

Oel 0-22 cm. Dark brown (7,5 YR 3/2) partly decomposed coherent organic material, plastic, non-sticky, clear smooth boundary to

Oa 22-50 cm. Black (5 YR 2/1) well-decomposed organic material, strong medium granular structure, plastic, non-sticky, abrupt smooth boundary to

Lco 50-85 cm. Greyish brown (2,5 Y 5/2) gyttje with calcium carbonate, many shells, no clearly expressed structural aggregates, plastic, non-sticky.

Oe2 85-105 cm. Very dark greyish brown (10 YR 3/2) partly decomposed organic material with some gyttje, many shells, no clearly expressed structure, plastic, non-sticky

C 105- cm. Olive (5 Y 5/3) silty clay loam with calcium carbonate, weak blocky structure, plastic, non-sticky.

Øllemose profile 4

Oa 0-12 cm. Dark reddish brown (5 YR 2/2) well decomposed organic material, medium granular structure, plastic, sligthly sticky, clear smooth boundary to

Oel 12-26 cm. Dark reddish brown (5 YR 2/2) partly decomposed organic material, weak granular structure, plastic, non-sticky, clear smooth boundary to

Oe2 26-70 cm. Black (5 YR 2/1) partly decomposed organic material with a few more light coloured parts consisting of undecomposed plant residues, plastic, non-sticky, diffuse smooth boundary to

Oe3 70-110 cm. Black (5 Y 2/2) partly decomposed organic material with some gyttje, weak coarse blocky structure, plastic, non-sticky, considerable outflow of water indicates high water content and high permeability, clear irregular boundary to

C1 110-135 cm. Olive grey (5 Y 5/2) loam with calcium carbonate, no clearly expressed structure, plastic, slightly sticky, clear smooth boundary to

C2 135- cm. Dark olive grey (5 Y 3/2) sandy loam, layered, some of the layers with a small content of gyttje, contains calcium carbonate, plastic, slightly sticky. The horizon is rather soft, a harder soil layer is present at 230 cm depth.

Øllemose profile 5

Oal 0-25 cm. Very dark greyish brown (10 YR 3/2) well-decomposed organic material, friable, strong medium granular structure, plastic, non-sticky, clear wavy boundary to

Oa2 25-45 cm. Very dark grey (5 YR 3/1) well-decomposed organic material, vertical up to 1 cm wide cracks, reddish brown iron concretions surrounding root holes, moderate very coarse columnar and coarse blocky structure, clear smooth boundary to

C1 45-58 cm. Very dark grey (5 Y 3/1) sand, layered, some organic residues and some lighter parts occur, weak platy structure, non-plastic, non-sticky, abrupt smooth boundary to

C2 58-80 cm. Olive grey (5 Y 5/2) loamy sand, a few large undecomposed plant residues and a few reddish brown mottles occur, non-plastic, non-sticky, abrupt smooth boundary to

C3 80- cm. Dark olive grey (5 Y 3/2) loamy sand, layered, contains calcium carbonate, non-plastic, non-sticky.

Gammellung profile

Oa 0-14 cm. Black (5 YR 2/1) well-decomposed organic material, moderate fine granular structure, loose but to some extent coherent due to plant roots, plastic, non-sticky, abrupt wavy boundary to

Lca1 14-25 cm. Greyish brown (10 YR 5/2) calcareous material, shells are present, weak fine granular structure, plastic, slightly sticky, clear smooth boundary to

Lca2 25-59 cm. Pale yellow (2.5 Y 7/4) calcareous material with a few partly decomposed plant residues and some shells, layered, weak subangular blocky structure, plastic, slightly sticky, diffuse smooth boundary to

Lca3 59-70 cm. Brown (10 YR 5/3) calcareous material with af few partly decomposed plant residues and small shells subangular blocky structure, plastic, slightly sticky, clear smooth boundary to

C 70- cm. Light grey to grey (5 Y 6/1) sandy loam with calcium carbonate, layered, plastic, non-sticky.

Kirkelyng profile 1

Oe 0-12 cm. Black (5 YR 2/1) partly decomposed organic material, strong medium granular structure, non-plastic, non-sticky, clear smooth boundary to

Oi1 12-30 cm. Very dark grey (10 YR 3/1) undecomposed organic material, coherent, no clearly expressed structural aggregates, plastic, non-sticky, clear wavy boundary to

Oi2 30-40 cm. Dark yellowish brown (10 YR 3/4) undecomposed organic material, coherent, no clearly expressed structural aggregates, plastic, non-sticky, abrupt wavy boundary to

Oi3 40-54 cm. Variegated very dark grey (10 YR 3/1) and dark yellowish brown (10 YR 3/4) undecomposed organic material, very weak platy structure, plastic, non-sticky, abrupt smooth boundary to

Lco1 54-106 cm. Very dark greyish brown (10 YR 3/2) gyttje, coarse columnar and fine platy structure, elastic, non-sticky, abrupt smooth boundary to

Lco2 106-108 cm. Dark, greyish brown (2,5 Y 4/2) gyttje, layered, many shells, elastic, non-sticky, abrupt smooth boundary to

C 108- cm. Grey (5 Y 5/1) loam with calcium carbonate, no clearly expressed structural aggregates, plastic, sticky.

Kirkelyng profile 2

Oi1 0-7 cm. Dark reddish brown (5 YR 3/3) organic material consisting of practically undecomposed residues of *Calluna vulgaris*, clear wavy boundary to

Oe1 7-20 cm. Black (5 YR 2/1) partly decomposed organic material, strong fine granular structure, somewhat coherent, plastic, non-sticky, diffuse smooth boundary to

Oe2 20-47 cm. Black (5 YR 2/1) partly decomposed organic material, weak fine granular structure, plastic, non-sticky, clear irregular boundary to

Oi2 47-110 cm. Alternating dark brown (7,5 YR 3/2) and black (5 YR 2/1) layers of undecomposed organic material, coherent within each layer but layers are easily separated, plastic, non-sticky. A 2 cm thick dark yellowish brown (10 YR 3/4) layer of material with identical properties is present immediately above the boundary to the next horizon. A strong outflow of water takes place from this layer. Abrupt smooth boundary to

Lco1 110-155 cm. Very dark greyish brown (10 YR 3/2) gyttje, weak platy structure, elastic, non-sticky, abrupt smooth boundary to

Lco2 155-170 cm. Dark brown (7,5 YR 3/2) gyttje, shells abundant, weak platy structure, elastic, non-sticky, abrupt smooth boundary to

Lco3 170-185 cm. Dark brown (7,5 YR 3/2) gyttje with clear layering and few shells, platy structure, elastic, non-sticky, abrupt smooth boundary to

C 185- cm. Olive grey (5 Y 5/2) silt loam with calcium carbonate, no clearly expressed structural aggregates, slightly plastic, slightly sticky.

Kroglyng profile

Oe1 0-8 cm. Dark reddish brown (5 YR 2/2) partly decomposed organic material, somewhat coherent, moderate fine granular structure, plastic, non-sticky, diffuse smooth boundary to

Oa 8-24 cm. Black (5 YR 2/1) well-decomposed organic material, moderate medium granular structure, plastic, non-sticky, clear almost smooth boundary to

Oe2 24-36 cm. Dark reddish brown (5 YR 2/2) and black (5 YR 2/1) partly decomposed organic material, somewhat coherent, weak granular structure, plastic, non-sticky, clear wavy boundary to

Oi 36-64 cm. Dark brown (7,5 YR 3/2) undecomposed organic material, strongly coherent, plastic, non-sticky, abrupt smooth boundary to

Oe3 64-70 cm. Very dark grey (10 YR 3/1) partly decomposed organic material, no clearly expressed structural aggregates, plastic, non-sticky, clear smooth boundary to

Lco1 70-83 cm. Dark reddish brown (5 YR 2/2) gyttje, with a few undecomposed plant residues, platy structure, elastic non-sticky, clear smooth boundary to

Lco2 83-105 cm. Black (5 Y 2/1) gyttje, with a few undecomposed plant residues, platy structure, elastic, non-sticky, abrupt smooth boundary to

C 105- cm. Grey (5 Y 5/1) loam, no clearly expressed structural aggregates, plastic, slightly sticky.

With the possible exception of the Gammellung profile all the soils may be classified as organic soils or, according to Soil Taxonomy (1975), histosols. The nature of the Gammellung profile is similar to that of the remaining soils but the fact that the major part of the peat layer has been removed through excavation may formally exclude this profile from the group of organic soils or histosols. The shallow peat layer overlies a layer of almost pure calcium carbonate deposited from water. The horizon below the calcium carbonate consists of a sorted sandy loam without stones, probably deposited in water.

In Øllemose the thickest peat layer is found in profile 4 but profile 3 is deeper and would probably have had a still thicker peat layer if no excavation had been made on this locality. The organic material in Øllemose is relatively well decomposed. In the lower parts of the deep profiles (3 and 4) layers consisting of or containing gyttje are found. Below these layers mineral material is present. This is probably deposited in water since stones are absent. Only in the C3 horizon of profile 5 a few rounded pebbles have been found.

Table 1. Water content, bulk density and shrinkage

Profile and depth, cm	Horizon	Water content, % by volume	Water content, % by weight	Bulk density g/cm³ dry	Bulk density g/cm³ wet	Dry soil volume in % of wet soil volume
Øllemose 1						
5-33	Oe	71	197	0.36	1.07	-
33-76	Oa	84	494	0.17	1.01	25
Øllemose 2						
0-48	Oa1	83	377	0.22	1.05	30
48-72	Oa2	88	629	0.14	1.02	10
72-	C	71	101	0.70	1.41	40
Øllemose 3						
22-50	Oa	89	636	0.14	1.03	-
Øllemose 4						
12-26	Oe1	84	382	0.22	1.06	10
26-70	Oe2	89	890	0.10	0.99	25
70-110	Oe3	92	836	0.11	1.03	10
Øllemose 5						
0-25	Oa1	71	178	0.40	1.11	-
25-45	Oa2	80	205	0.39	1.19	25
Gammellung						
25-59	Lca2	86	226	0.38	1.24	55
59-70	Lca3	84	210	0.40	1.24	55
Kirkelyng 1						
12-30	Oi1	84	840	0.10	0.94	-
30-40	Oi2	90	1125	0.08	0.98	-
54-106	Lco1	93	1329	0.07	1.00	10
Kirkelyng 2						
20-47	Oe2	85	772	0.11	0.96	30
47-110	Oi2	93	1163	0.08	1.01	25
110-155	Lco1	93	1163	0.08	1.01	10
155-170	Lco2	91	827	0.11	1.02	10
170-185	Lco3	92	1150	0.08	1.02	10
Kroglyng						
8-24	Oa	85	472	0.18	1.03	30
36-64	Oi	90	1000	0.09	0.99	20
70-83	Lco1	94	1175	0.08	1.02	<10
83-105	Lco2	89	890	0.10	0.99	<10

The organic material in Kirkelyng and Kroglyng is more poorly decomposed. The lower layers in these profiles consist of gyttje with an elastic consistence, almost like rubber. This material is layered and upon drying it shrinks to a small fraction of its original volume and becomes extremely hard. The mineral material below the organic horizons is a rather soft loam without any coarse particles.

PHYSICAL PROPERTIES OF THE PEAT

Water content, bulk density and shrinkage of samples from selected horizons are shown i Table 1. As described in the section on methods the samples were saturated with

Table 2. Organic C and N, $CaCO_3$ and pH

Profile and depth, cm	Horizon	pH H_2O	pH $CaCl_2$	% $CaCO_3$	% C	% N	C/N
Øllemose 1							
5-33	Oe	6.30	6.08		32.55	2.36	14
33-76	Oa	6.03	5.93		39.20	2.42	16
76-90	C1	8.17	7.25	1.09	1.18	0.11	11
90-107	C2	7.99	7.43	12.00	0.24	0.013	18
107-	C3	8.20	7.52	15.82	0.59	0.023	26
Øllemose 2							
0-48	Oa1	5.59	5.50		29.07	1.95	15
48-72	Oa2	6.57	6.50		25.20	1.87	13
72-96	C	7.66	7.08	0.04	3.16	0.26	12
Øllemose 3							
0-22	Oe1	5.63	5.49		43.32	1.82	24
22-50	Oa	5.95	5.53		37.13	2.56	15
50-85	Lco	7.70	7.26	52.34	20.98	1.77	12
85-105	Oe2	7.74	7.21	11.28	33.44	2.56	13
105-	C	7.76	7.30	8.57	6.56	0.48	14
Øllemose 4							
0-12	Oa	5.86	5.68		27.25	2.17	13
12-26	Oe1	5.59	5.40		29.11	2.04	14
26-70	Oe2	5.56	5.39		42.38	1.87	23
70-110	Oe3	6.83	6.48		30.49	2.42	13
110-135	C1	7.59	7.11	1.69	4.71	0.41	11
135-	C2	7.87	7.25	3.78	1.46	0.18	8
Øllemose 5							
0-25	Oa1	6.18	5.84		25.89	2.44	11
25-45	Oa2	6.25	6.13		28.60	1.79	16
45-58	C1	6.74	6.26		6.12	0.53	12
58-80	C2	7.22	6.57	0.05	0.60	0.037	16
80-	C3	7.75	7.21	1.80	0.54	0.039	14
Gammellung							
0-14	Oa	6.48	6.47		39,68	2.51	16
14-25	Lca1	7.68	7.45	78.33	8.75	0.86	10
25-59	Lca2	7.64	7.39	86,32	5.80	0.57	10
59-70	Lca3	7.53	7.33	83.16	6.02	0.34	18
70-	C	7.85	7.50	15.57	0,46	0.035	13
Kirkelyng 1							
0-12	Oe	5.70	5.43		45.58	1.06	43
12-30	Oi1	5.80	5.53		46.93	0.74	63
30-40	Oi2	5.83	5.57		48.93	1.43	34
40-54	Oi3	5.57	5.36		47.78	1.89	25
54-106	Lco1	6.33	6.19		45.72	4.04	11
106-108	Lco2	7.14	7.07	20.02	22.58	1.84	12
108-	C	7.66	7.32	16.85	1.12	0.092	12
Kirkelyng 2							
7-20	Oe1	3.67	3.20		47.63	1.23	39
20-47	Oe2	3.98	3.71		49.89	0.95	53
47-110	Oi2	5.23	4.93		45.99	1.19	39
110-155	Lco1	6.40	6.27		48.06	4.79	10
155-170	Lco2	7.22	7.20	32.29	30.13	2.69	11
170-185	Lco3	7.19	6.95	13.31	36.83	3.20	12
185-	C	7.59	7.41	30.71	3.33	0.23	14
Kroglyng							
0-8	Oe1	3.59	3.18		47.84	1.07	45
8-24	Oa	3.72	3.27		47.94	0.92	52
24-36	Oe2	4.03	3.67		50.07	1.73	29
36-64	Oi	5.10	4.60		46.61	1.25	37
64-70	Oe3	5.40	5.07		47.92	1.74	28
70-83	Lco1	5.30	5.12		41.29	3.21	13
83-105	Lco2	5.47	5.31		45,32	3.77	12
105-	C	6.43	6.21		2.01	0.16	13

water at zero tension before the determination of the water content. However, the saturation seems to have been incomplete in some cases since some of the samples apparently have wet bulk densities below 1 g/ccm. Some

Table 3. Texture of mineral horizons

Profile and depth, cm	Horizon	Coarse sand 0,2-2 mm	Fine sand 0,02-0,2 mm	Silt 0,002-0,02 mm	Clay <0,002 mm	Textural class
Øllemose 1						
76-90	C1	40.0	42.7	9.2	8.1	Sandy loam
90-107	C2	20.3	56.0	13.4	10.3	Sandy loam
107-	C3	3.9	39.6	31.0	25.5	Loam
Øllemose 2						
72-	C	8.0	51.1	24.1	16.8	Loam
Øllemose 3						
105-	C	1.3	29.7	39.7	29.3	Silty clay loam
Øllemose 4						
110-135	C1	4.1	46.2	28.9	20.8	Loam
135-	C2	8.0	61.0	17.0	14.0	Sandy loam
Øllemose 5						
45-58	C1	15.7	78.8	5.5	0.0	Sand
58-80	C2	12.7	79.2	3.8	4.3	Loamy sand
80-	C3	27.5	62.9	4.6	5.0	Loamy sand
Gammellung						
70-	C	17.4	46.6	21.2	14.8	Sandy loam
Kirkelyng 1						
108-	C	4.0	59.9	20.3	15.8	Loam
Kirkelyng 2						
185-	C	1.8	44.9	35.5	17.8	Silt loam
Kroglyng						
105-	C	4.8	51.8	23.7	19.7	Loam

of the water contents and the wet bulk densities given in Table 1 may therefore be low. Despite this, it is clear from Table 1 that all samples from organic horizons have a high water content. With two exceptions, more than 80% of the volume of the samples is accounted for by water, and in the poorly decomposed organic material from Kirkelyng and Kroglyng as well as in the gyttje from these localities the water content, based on volume, is 90-95%.

A similar water content is to be expected in the field if the soil is saturated. However, in deep horizons the water content under field conditions may be different from that determined in the laboratory because these horizons carry the load from the overlying horizons and because the water here will be at a pressure higher than zero. The two factors will counteract each other and it is not possible to estimate their combined effect. However, the effect will probably be small because all horizons are relatively close to the surface. The water content in the field will, of course, be smaller if the soil is unsaturated which is the case in some of the upper horizons during part of the year.

CHEMICAL AND MECHANICAL COMPOSITION

In Table 2 the contents of organic carbon and nitrogen are listed for all horizons. The highest contents of carbon (approx. 50%) are found in the poorly decomposed material from Kirkelyng and Kroglyng. This indicates that the content of inorganic constituents in these materials is very low. The materials have a low nitrogen content and, accordingly, a high carbon-nitrogen ratio. This is consistent with their low degree of decomposition. By contrast the gyttje from the same localities has a rather high nitrogen content and, consequently, a low carbon-nitrogen ratio.

Tabel 4. Adsorbed cations, cation exchange capacity and base saturation percentage

Profile and depth, cm	Horizon	Adsorbed cations, meq/100 g Ca	Mg	K	Na	H	CEC, meq/100 g	Base saturation percentage
Øllemose 1								
5-33	Oe	125.2	2.62	0.15	0.46	14.7	143.1	89.7
33-76	Oa	99.8	3.32	0.07	0.46	18.8	122.5	84.6
76-90	C1		0.52	0.05	0.06	1.83		
90-107	C2		0.80	0.14	0.36			
107-	C3		0.96	0.32	0.06			
Øllemose 2								
0-48	Oa1	78.8	3.26	0.16	0.62	20.2	103.0	80.4
48-72	Oa2	64.5	2.68	0.13	0.48	3.67	71.5	94.9
72-	C		1.18	0.18	0.22			
Øllemose 3								
0-22	Oe1	63.2	5.20	3.04	3.12	30.0	104.6	71.3
22-50	Oa	103.6	4.28	0.14	0.78	24.3	133.1	81.7
50-85	Lco		1.96	0.05	0.44			
85-105	Oe2		2.12	0.11	0.46			
105-	C		1.18	0.24	0.16			
Øllemose 4								
0-12	Oa	68.6	2.40	0.28	0.60	17.3	89.7	80.7
12-26	Oe1	77.6	2.40	0.12	0.52	24.0	104.6	77.1
26-70	Oe2	98.8	3.26	0.11	0.64	29.7	132.5	77.6
70-110	Oe3	69.0	2.14	0.19	0.60	3.83	71.9	94.9
110-135	C1		0.98	0.14	0.18			
135-	C2		0.72	0.10	0.12			
Øllemose 5								
0-25	Oa1	74.4	2.02	0.25	0.40	12.7	89:8	85.9
25-45	Oa2	99.8	2.86	0.08	0.44	10.5	113.7	90.8
45-58	C1	17.3	0.68	0.02	0.10	5.67	23.8	76.1
58-80	C2		0.56	0.05	0.06			
80-	C3		0.46	0.06	0.08			
Gammellung								
0-14	Oa	88.8	4.34	1.48	0.90	3.83	99.4	96.1
14-25	Lca1		1.22	0.06	0.24			
25-59	Lca2		1.00	0.04	0.18			
59-70	Lca3		0.90	0.02	0.16			
70-	C		0.62	0.15	0.08			
Kirkelyng 1								
0-12	Oe	61.6	2.58	0.76	0.70	20.0	85.6	76.6
12-30	Oi1	46.6	1.66	0.10	0.78	16.5	65.6	74.9
30-40	Oi2	48.9	1.36	0.16	0.82	21.0	72.2	70.9
40-54	Oi3	64.5	1.48	0.17	0.70	30.3	97.2	68.8
54-106	Lco1	51.2	1.24	0.38	0.76	8.00	61.6	87.0
106-108	Lco2		0.92	0.25	0.36			
108-	C		0.46	0.20	0.12			
Kirkelyng 2								
7-20	Oe1	14.9	2.64	0.56	0.48	85.3	103.9	17.9
20-47	Oe2	25.8	2.86	0.19	0.48	83.0	112.3	26.1
47-110	Oi2	56.7	1.90	0.06	0.52	36.5	95.7	61.9
110-155	Lco1	47.6	1.04	0.10	0.70	8.17	57.6	85.8
155-170	Lco2		1.00	0.20	0.42			
170-185	Lco3		1.16	0.40	0.52			
185-	C		0.52	0.28	0.22			
Kroglyng								
0-8	Oe1	14.0	3.42	0.68	0.50	86.3	104.9	17.7
8-24	Oa	20.0	3.56	0.25	0.50	97.0	121.3	20.0
24-36	Oe2	30.3	2.70	0.07	0.54	85.2	118.8	28.3
36-64	Oi	44.4	1.88	0.05	0.46	36.5	83.3	56.2
64-70	Oe3	54.7	2.06	0.10	0.72	36.0	93.6	61.5
70-83	Lco1	35.1	1.56	0.16	0.66	22.2	59.7	62.8
83-105	Lco2	38.3	1.62	0.06	0.58	18.5	59.1	68.7
105-	C	15.7	0.62	0.20	0.16	5.3	22.0	75.9

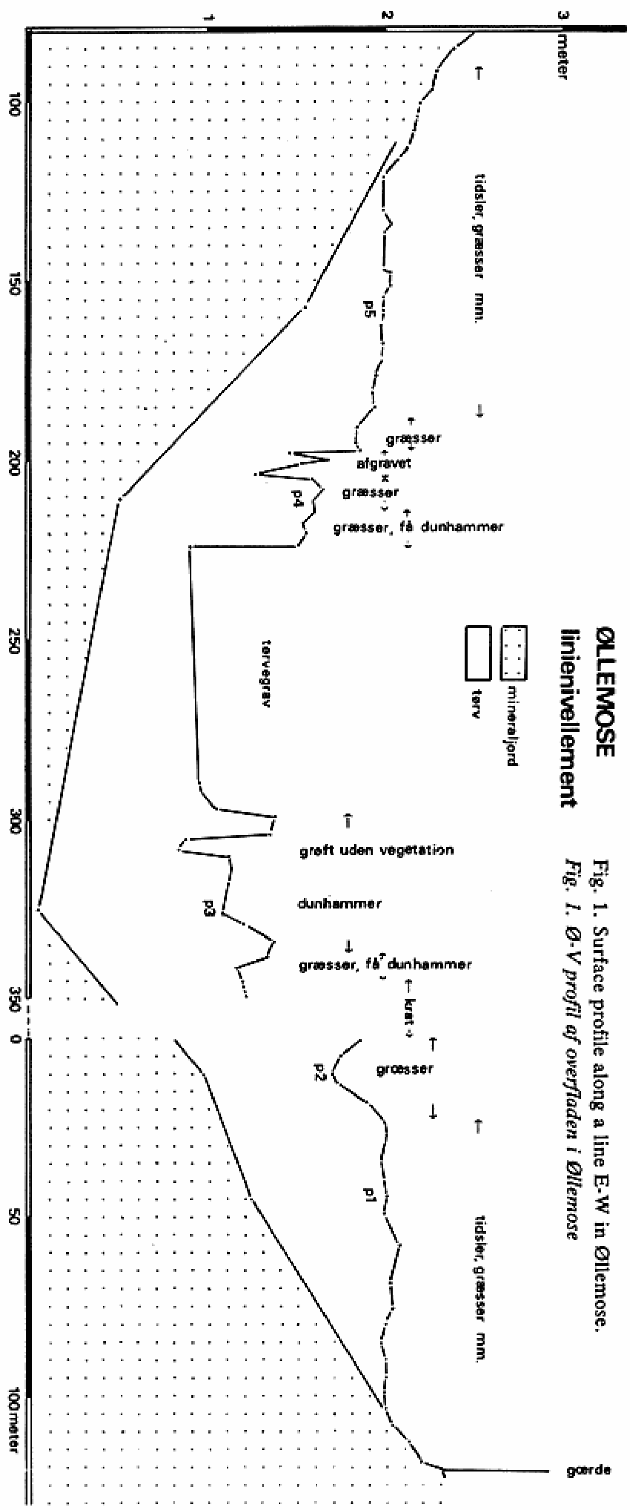

Fig. 1. Surface profile along a line E-W in Øllemose.
Fig. 1. Ø-V profil af overfladen i Øllemose

In Øllemose and Gammellung the material has lower carbon content, higher nitrogen content and hence a rather low carbon-nitrogen ratio. This is in agreement with the higher degree of decomposition of this material as compared with that from Kirkelyng and Kroglyng.

As shown in Table 2 calcium carbonate is present in the lower part of all profiles except Kroglyng. The highest content is found in Gammellung, but high contents are also found in the Lco-horizon of profile 3 in Øllemose (52%), and in the Lco2 horizon of profile 2 in Kirkelyng (32%). The pH values, also shown in Table 2, vary according to the properties of the horizons. All calcareous horizons have pH values 7-8. The upper horizons in Øllemose are neutral to sligthly acid while upper horizons of the Kirkelyng 2 and Kroglyng profiles are strongly acid. Very low pH values are not found in Kirkelyng profile 1, probably because the upper peat layers have been removed through excavation.

The texture of the mineral horizons is shown in Table 3. Since these horizons contain no gravel or stones they are thought to represent sediments formed in lakes existing prior to the formation of the peat.

The content of adsorbed cations, the cation exchange capacity and the base saturation percentage are listed in Table 4. For horizons containing calcium carbonate, cation exchange capacity and base saturation percentage could not be calculated. In accordance with the rather high pH values, the base saturation percentage is fairly high in most horizons. High content of exchangeable acidity and low base saturation percentages are found only in the upper horizons of the Kirkelyng 2 and Kroglyng profiles which also have low pH values. Among the adsorbed metal ions, calcium is dominating.

SURFACE OF ØLLEMOSE

The surface profile along a line with east-west direction in Øllemose is shown in Fig. 1.

The irregular surface is mainly due to the excavation of peat which has been carried out on this locality. The thickness of the organic layers is also shown in Fig. 1. This is based on the profile investigations and is therefore known in five points only, but with this limitation Fig. 1 gives an impression of the thickness of the peat layers.

GROUND WATER LEVEL

The ground water levels on the four localities investigated are shown in Fig. 2. All records show a normal cyclus with a maximum ground water level during the winter. During the summer the ground water level decreases and the minimum occurs in the autumn. The largest fluctuations take place in Gammellung where the difference between maximum and minimum is above 1 m.

Considerable fluctuations occur in Øllemose too, but in Kirkelyng and Kroglyng the fluctuations are fairly small. These different fluctuation patterns are due to differences in topography and drainage conditions. During the winter Gammellung and the central part of Øllemose become flooded. The summer of 1976 was extremely dry and the ground water level has probably been considerably lower than in 1977. This is also in accordance with the very low ground water levels recorded at the measurements in November 1976.

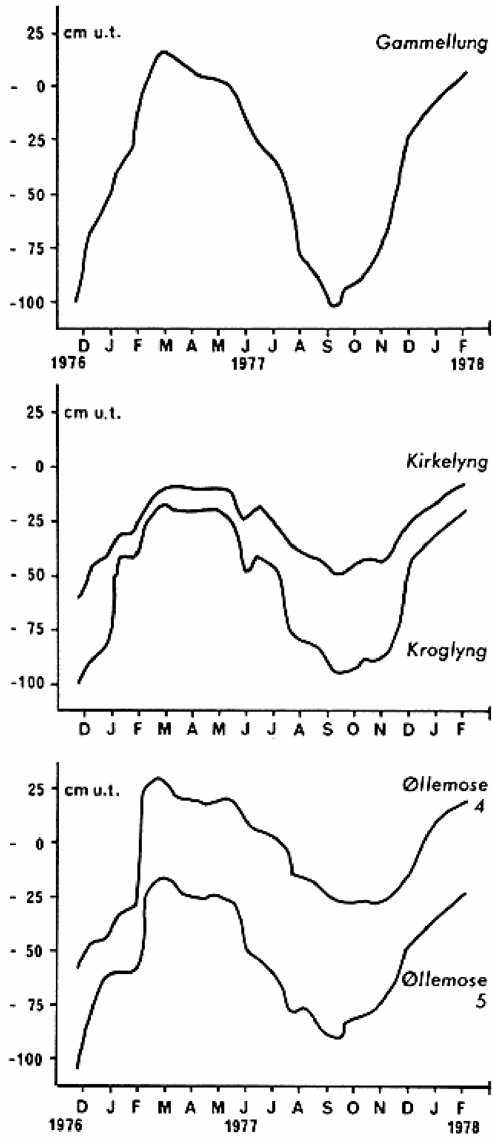

Fig. 2. The groundwater levels at five localities.

Fig. 2. Svingninger i grundvandstanden målt på fem lokaliteter.

CONCLUSIONS

It may be concluded from the results of the investigation that a lowering of the ground water, which is close to the surface on all the localities investigated, will have a considerable effect on the soils. Even a partial drying of the peat will cause a severe shrinking. A drying will take place soon after a ground water lowering, and a rapid subsidence due to shrinking can therefore be expected. Since many of the soil layers are practically purely organic they will be decomposed in the presence of oxygen. This will also cause subsidence although this will be more slow than the subsidence caused by shrinking.

The extent of subsidence will vary from one locality to another. The largest subsidence is possible in Kirkelyng and Kroglyng where the peat as well as the gyttje have extremely high water contents and a low contents of inorganic constituents. In Gammellung where the peat to a large extent has been removed by excavation there will hardly be any subsidence at all since the calcareous material will neither shrink nor become decomposed. It may gradually become dissolved by leaching rain water, but this is a slow process which requires a very long period to proceed to a measurable extent.

In Øllemose the peat has a smaller water content and a higher content of inorganic constituents. Hence, the potential subsidence is lower here than in Kirkelyng and Kroglyng. On the other hand, the peat in Øllemose is rich in mineral nutrients and nitrogen, and it has a neutral or only slightly acid reaction. This will provide favourable conditions for the organisms involved in decomposition of the peat, and it will give rise to a mobilization of plant nutrients, particularly nitrogen. Hence, the oxidation will be promoted by these factors, and the flora will be affected by the high contents of available nutrients. In Kirkelyng and Kroglyng the chemical conditions for decomposition is less favourable because of the low content of nitrogen and other nutrients, and because of the more acid reaction. There is not likely to be any mobilization of nitrogen within the initial stages of decomposition. Later when decomposition has progressed further and when it involves the gyttje layers, which are rich in nitrogen, a nitrogen mobilization may be expected.

As discussed in the introduction the extent of subsidence depends not only on the nature and the thickness of the peat layers but also on the depth of the ground water level. The potential subsidence will therefore increase with increasing depth of the ground water, but at a sufficiently low ground water level the potential subsidence will be greater in Kirkelyng and Kroglyng than in Øllemose. For entirely organic materials the maximum subsidence will equal the thickness of the peat layers, but a subsidence to this extent will require an extremely long period and in practice it will not be attained because the peat always contains some inorganic constituents. However, from the investigations quoted in the introduction it is clear that areas like those investigated here will be subject to a considerable and rapid subsidence as well as a change in chemical properties if the ground water level is lowered.

RESUME

Organiske jorde eller tørvejorde dannes på lokaliteter, hvor en høj grundvandstand hæmmer nedbrydningen af det organiske stof, som produceres af vegetationen. Sænkes grundvandet, vil tørvedannelsen ophøre, og den allerede dannede tørv vil undergå en række forandringer, bl.a. vil den skrumpe kraftigt, fordi en stor del af tørvens volumen udgøres af vand. Desuden vil der ske en komprimering af tørven, fordi opdriften på denne reduceres, og denne komprimering vil ikke være begrænset til tørvelagene over grundvandspejlet. På længere sigt sker der en større eller mindre bortoxidering af tørven, fordi luftens ilt får adgang til tørvelagene. I forening giver disse processer anledning til en sætning, som ifølge talrige undersøgelser og erfaringer kan være meget betydelig, og som kan foregå meget hurtigt. Dens omfang vil afhænge af størrelsen af grundvandssænkningen samt af tørvelagenes tykkelse og karakter. I forbindelse med tørvens oxidering kan der ske en frigørelse af plantenæringsstoffer, hovedsageligt kvælstof, og dette kan påvirke floraen på de pågældende moselokaliteter.

En sænkning af grundvandspejlet kan ske i forbindelse med vandindvinding, og den her beskrevne undersøgelse blev gennemført for at vurdere de jordbundsmæssige konsekvenser af en eventuel sænkning af grundvandstanden på nogle mosearealer, som ligger i et potentielt vandindvindingsområde i det sydlige Sjælland.

Undersøgelsen har omfattet fire moselokaliteter, nemlig Øllemose, som ligger nordvest for Haslev, samt Gammellung, Kirkelyng og Kroglyng, som alle ligger øst for Herlufmagle. Øllemose og Gammellung er lavmoser med 0,3-1,6 m tykke tørvelag. En del af tørven er fjernet ved afgravning, især i Gammellung, hvor afgravningen i store områder har blottet den underliggende mosekalk. Egentlig mosekalk forekommer ikke i Øllemose, men de nedre tørvelag samt de uorganiske jordlag under tørven er kalkholdige.

I Kirkelyng og Kroglyng findes øverst en spagnumtørv, derunder lavmosetørv, og nederst gytje, som består næsten udelukkende af organisk materiale. Tørvelagenes tykkelse varierer fra 0,2 til 2,5 m, men en del er fjernet ved afgravning. I Kirkelyng er gytjen og de derunder liggende uorganiske jordlag kalkholdige.

Tørven i Øllemose og Gammellung er ret godt omsat. Kulstofindholdet er relativt lavt, hvilket tyder på et betydeligt indhold af uorganiske bestanddele. Kulstof-kvælstofforholdet er forholdsvis lavt, og volumenvægten varierer fra 0,1 til 0,4. I mættet tilstand indeholder tørven 70-90 vol.% vand. Enkelte tørvelag er svagt sure, men de fleste har dog pH-værdier omkring neutralpunktet. Kalkholdige lag har noget højere pH-værdier.

I Kirkelyng og Kroglyng er tørven væsentligt dårligere omsat. Kulstofindholdet er højt, og tørven indeholder derfor næppe

større mængder af uorganiske bestanddele. Kulstof-kvælstofforholdet er højt, og volumenvægten varierer fra 0,08 til 0,18. Den mættede tørv indeholder 84-94 vol.% vand. De øverste tørvelag er stærkt sure, og pH-værdierne vokser med dybden. I gytjen er omsætningsgraden, kulstofindholdet, volumenvægten og vandindholdet nogenlunde som i tørven, men kulstof-kvælstofforholdet er 2-5 gange så lavt pH-værdierne er højere end i tørven, og de højeste værdier træffes naturligvis i de kalkholdige gytjelag.

Resultaterne af undersøgelsen viser, at en sænkning af grundvandspejlet kan medføre en betydelig sætning på alle lokaliteterne med undtagelse af Gammellung, hvor tørvelaget er meget tyndt. Den største sætning vil kunne ske i Kirkelyng og Kroglyng, hvor tørvelagene er tykke, vandindholdet stort og indholdet af uorganiske bestanddele lavt. På den anden side vil der på disse lokaliteter være relativt dårlige betingelser for biologisk nedbrydning af tørvemassen, fordi denne er ret sur og har et lavt indhold af næringsstoffer, især kvælstof. Der vil derfor heller ikke i nedbrydningens indledende stadier ske nogen kendelig frigørelse af kvælstof. En større frigørelse af kvælstof kan derimod forventes i Øllemose.

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Resultaterne af undersøgelsen viser, at en sænkning af grundvandspejlet kan medføre en betydelig sætning på alle lokaliteterne med undtagelse af Gammellung, hvor tørvelaget er meget tyndt. Den største sætning vil kunne ske i Kirkelyng og Kroglyng, hvor tørvelagene er tykke, vandindholdet stort og indholdet af uorganiske bestanddele lavt. På den anden side vil der på disse lokaliteter være relativt dårlige betingelser for biologisk nedbrydning af tørvemassen, fordi denne er ret sur og har et lavt indhold af næringsstoffer, især kvælstof. Der vil derfor heller ikke i nedbrydningens indledende stadier ske nogen kendelig frigørelse af kvælstof. En større frigørelse af kvælstof kan derimod forventes i Øllemose.

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