Understanding and Managing Organic Matter in Soils, Sediments, and Waters.
R.S. Swift and K.M. Spark (Eds)

Organic indices for the decomposition of peat in a high-moor peatland under severe drying and vegetation change

Renzo Kondo and Kiyoshi Tsutsuki

Laboratory of Land Resource Science, Obihiro University of Agriculture and Veterinary Medicine, Inada-cho, Obihiro, Hokkaido 080-8555 Japan.

Abstracts

In a mire severely suffering from drying and subsidence, peat samples were collected on a transect line which passes through the original *Sphagnum* community and the invading *Sasa* community. Several physical and chemical properties and indices for the degree of decomposition of peat were determined to clarify the effect of environmental changes. The degree of humification and bulk density were lower, while fibre contents and C/N were larger at the central part of the peatland where the community of *Sphagnum* remained. In accordance with surface soil drying, total nitrogen content, ash content, and the degree of humification increased, while C/N ratio, fibre contents, field moisture content, and bulk density decreased. Yields of total phenolic compounds were larger at the sites where *Sasa senanensis* thrived. Yields of long chain fatty acids tended to increase as the decomposition of peat proceeded. Thus, organic characteristics of peat were shown to be appropriate indices for the environmental changes in the peatland.

Key words: CuO-NaOH oxidation, fibre content, humification, phenolic compounds, *Sphagnum*, subsidence

Introduction

No more than 100 years ago, vast area of Ishikari plain in Hokkaido was covered by a 60,000 ha of peatland. At present the natural mire vegetation remains only in a very small area (ca. 50 ha) at Bibai city preserved by Hokkaido Agricultural Experiment Station. Even in 1960, southern half of this mire was a completely virgin highmoor peatland whose dominant vegetation was *Sphagnum* and sedges. In accordance with the development of drainage systems in the surrounding paddy and upland fields, the water in the mire was also drained. As a result, decomposition of peat and subsidence of peatland proceeded remarkably, and shrubs and *Sasa senanensis* invaded the high-moor peatland from the peripheral area. Accordingly, the original community of *Sphagnum* and sedges vegetation has diminished to as small as 1 ha area in the central part of the mire. In this study, several fundamental characteristics as well as organic constituents of peat were determined, to clarify how they are affected by the vegetation change and drying of peatland.

Material and methods

Bibai mire is located around 43°19′N, 141°49′E. The hydrology, vegetation, conservation and management of the lowland area including this mire have been described by Kasubuchi *et al.*, (1994), Miyaji *et al.*, (1995) and several papers by their colleagues of Hokkaido Agricultural Experiment Station. The cross section (west-east) of the mire is shown in Fig. 1.

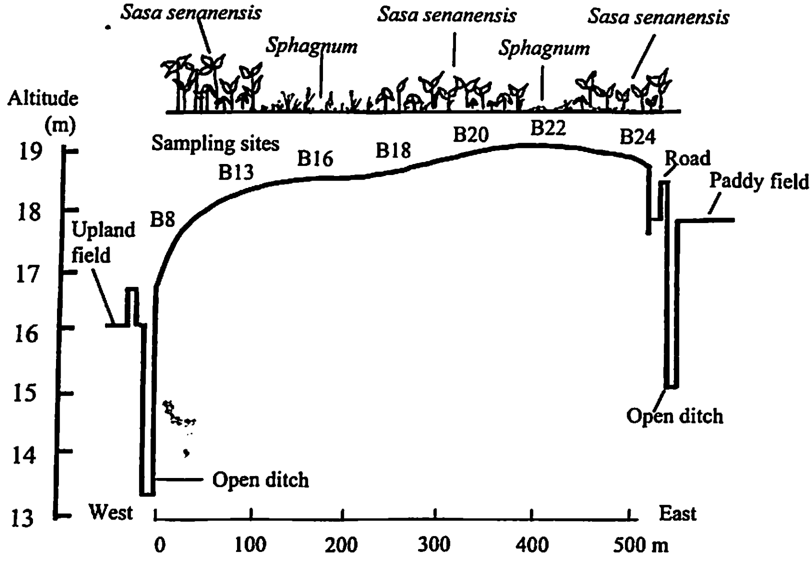

Figure 1 Cross section of Bibai peatland and the distribution of vegetation. Adapted from Kasubuchi *et al.*, (1994).

Surface of the mire subsides remarkably toward the west due to the drainage through the open ditch and the upland field. Due to the drying of surface peat layer, *Sasa senanensis* invades the mire from the peripheral area. The original *Sphagnum* vegetation remains only in a small area (1 ha) at the centre of the mire. Peat samples were collected from 16 sites on this transect line. Peat samples were collected in blocks up to the depth of 15 cm. Fibre contents, pyrophosphate index, pH ($CaCl_2$) (USDA 1984), and bulk density were determined using fresh samples. Unrubbed fibre content was determined by measuring the volumes of peat packed in a half-cut syringe (5 mL capacity) before and after washing out fine sapric material through a 100 mesh sieve. Rubbed fibre was the fibre which remained on the sieve after rubbing and washing. The result was an average of 10 measurements. Total carbon and nitrogen, ash, and the degree of humification (Kaila 1956) were determined for air dried samples. To obtain the degree of humification, peat (1.0 g) was extracted with 100 mL of 0.025 mol L^{-1} sodium pyrophosphate for 18 hr. The extract was filtered and diluted 5 times, the optical density at 550 nm and 340 nm was recorded and multiplied by 100. The content of fine roots of *Sasa senanensis* was determined by washing 7x7x7 cm block of peat with 0.1 mol L^{-1} NaOH and water on the sieves of 28 mesh and 70 mesh. Phenolic compounds after CuO-NaOH oxidation and fatty acids were determined according to Tsutsuki *et al.*, (1994, 1997).

Results and discussion

1) Contents of the root of Sasa senanensis in the peat layer (Table 1)

Fine roots of *Sasa senanensis* were not observed at the sites B15-17. Root contents were very large at B13 and B19 which were just outside the community of *Sphagnum*. *Sasa senanensis* grew most densely at the invading front into the *Sphagnum* community.

Table 1 Fundamental properties of peat samples in Bibai peatland.

Sampling site	Total C g kg^{-1}	Total N g kg^{-1}	C/N	Ash g kg^{-1}	pH (0.01mol L^{-1} $CaCl_2$)	Root content of *Sasa sen.* (g kg^{-1})
B8	384	18	22	293	4.0	4.3
B9	214	10	21	544	3.8	5.3
B11	394	21	19	383	4.6	6.9
B12	360	22	17	313	4.5	8.9
B13	390	18	22	221	5.0	36
B14	388	21	18	226	5.2	7.9
B15	367	11	35	192	4.5	0
B16	339	12	27	238	4.0	0
B17	347	14	24	248	4.2	0
B18	329	18	19	327	5.1	8.0
B19	386	20	19	196	3.8	33
B20	279	17	16	228	4.7	29
B21	380	17	22	246	4.9	28
B22	409	13	31	189	4.4	13
B23	383	20	19	235	3.9	16
B24	385	20	19	247	4.0	32

2) Physicochemical properties of peat soils (Table 1)

Total carbon contents of the peat soils showed no relationship with the change in vegetation nor with the dryness of the peatland. The remarkable local minimum at B9 site may be due to the deposition of mineral soil or volcanic ash. On the other hand, nitrogen content showed extremely low values at B15-17, where the community of *Sphagnum* remained. C/N ratio was maximum at the same sites. Another local maximum of C/N was observed at B22, where another small community of *Sphagnum* remained. Ash contents and values of pH ($CaCl_2$) were also lowest (148-248 g kg^{-1} for ash, 4.1-4.5 for pH) at B15-17. The pH exceeded 5.0 at the sites B14 and B18 which corresponded to the invading front of *Sasa senanensis*. The pH value was very low (< 4.0) also at the western and eastern edges of the peatland (B8-9, B23-24) where peat was extremely decomposed. Thus the low pH of the peat was due to two mechanisms, one was the living tissue of *Sphagnum* itself and the other was the decomposition of peat. On the other hand, new root of *Sasa senanensis* increased the pH of peat layer.

3) Indices of peat decomposition (Table 2)

Fibre content, field moisture content, bulk density, degree of humification, and pyrophosphate index of the peat layers are shown in Table 2.

Table 2 Indices of peat decomposition.

Sampling site	Unrubbed fibre (%)	Rubbed Fibre (%)	Field moisture g kg^{-1}	Bulk density Mg m^{-3}	Degree of humification by Kaila (1956) 340 nm	550 nm	Pyro-phosphate Index
B8	45.4	15.0	650	0.26	432	47	0
B9	45.6	21.8	740	0.30	292	37	0
B11	30.8	11.2	760	0.26	242	30	1
B12	30.8	10.8	750	0.13	294	36	0
B13	35.8	22.8	860	0.12	160	14	2
B14	21.2	12.4	880	0.12	277	27	5
B15	57.6	42.4	940	0.06	152	11	4
B16	61.6	45.6	950	0.05	155	14	3
B17	54.8	39.2	960	0.03	139	17	2
B18	29.0	18.6	860	0.13	306	28	1
B19	29.8	19.0	900	0.08	179	21	2
B20	36.6	23.4	880	0.10	169	18	3
B21	22.2	14.4	880	0.10	122	13	3
B22	29.0	21.2	900	0.09	157	15	3
B23	19.8	10.0	860	0.12	186	20	0
B24	29.8	10.8	840	0.17	315	45	0

Unrubbed fibre contents ranged between 20 - 60 per cent, while rubbed fibre was 7-46 per cent, one-third to one-forth of the former. Each fibre content was the largest at the sites of *Sphagnum* community. Unrubbed fibre contents at B8-9 sites in the western edge of the peatland were >45 per cent, but rubbed fibre contents in these sites were very low, 15-22 per cent. This is due to the oxidative deterioration of peat fibre. Field moisture content ranged between 650-960 g kg^{-1}. It was largest (940-960 g kg^{-1}) at B15-B17 (the community of *Sphagnum*) but decreased to 650 g kg^{-1} at western edge of the peatland. Bulk density showed an opposite tendency to the field moisture content. Degree of humification was also obtained from the optical density of pyrophosphate extract at 340 nm in addition to that at 550 nm as indicated by Kaila (1956). These values were the lowest at B15-17 and B22 but increased at the peripheral of the peatland. On the other hand, higher pyrophosphate index means the lower humification of peat. These values ranged between 0-5, and were large at the *Sphagnum* community sites but small at the peripheral site.

4) Correlation between the fundamental properties and decomposition indices of peat.

Total nitrogen content showed a highly negative correlation with C/N (r=-0.494**), ash content (-0.573**), unrubbed fibre (-0.492**), rubbed fibre (-0.450**), where *, ** and *** denote the level of significance at 5, 1, and 0.1 per cent, respectively. C/N ratio itself showed more significant correlation with unrubbed fibre (0.529**), rubbed fibre (0.607**), and degree of humification at 550 nm (-0.402*). Ash content showed highly significant negative correlation with total C (-0.844**), total N (-0.573**), field moisture contents (-0.635**), and a positive correlation with bulk density (0.686**). The pH ($CaCl_2$) of the soils showed no significant correlation with other indices. This was because the originally low pH of *Sphagnum* moss increased in the early stage of decomposition but decreased again as its decomposition proceeded further.

Degree of humification by Kaila (1956) was obtained from the optical densities of pyrophosphate extract of peat. A highly positive correlation (r=0.949***) existed between the optical densities at 550 nm and 340 nm. However, the optical density at 550 nm showed more significant correlation with other indices such as C/N (-0.402*), rubbed fibre (-0.448*), field moisture (-0.814***), and bulk density (0.780***) than that at 340 nm. This may be because the optical density of pyrophosphate extract at 550 nm represent the amount of humic substances in peat more correctly than that at 340 nm.

Leaves and stems of *Sphagnum* posses hyaline cells and retort cells, which can store large amount of water (Crum 1991). When the fibre of *Sphagnum* is decomposed, the capacity for water storage decreases. This is why the field moisture content decreased in association with the decomposition of peat. Field moisture content showed highly significant correlation with rubbed fibre (0.606*), ash contents (-0.635*), degree of humification at 550 nm (-0.814***) and 340 nm (-0.813*), and bulk density (-0.913*).

5) Total phenolic compounds and total fatty acid.

The yield of phenolic compounds after CuO-NaOH oxidation represents the amount of lignin components in the plant material. This value was larger for the coarse (>2 mm) fraction of peat, and also for the peat collected at the peripheral sites where the *Sasa* community thrived. At the sites of *Sphagnum* community, the yield of phenolic compounds in the coarse (>2 mm) fraction showed a local minimum. This may be because the lignin structure is not developed in the tissue of *Sphagnum*. In the eastern part of the peatland, B19-24, the yield of phenolic compounds from the fine (<2 mm) fraction of peat was as low as that in the central part. This may be because the tissue of *Sphagnum* still remained in the fine fraction of peat in the eastern area. In the western area, the yield of phenolic substances in the fine fraction was as large as that in the coarse fraction. The plant residue of *Sasa senanensis* may be also contained in the fine fraction of peat, because the decomposition of peat was very severe in this area.

The yield of total fatty acid was larger in the finer (<2 mm) fraction of peat than in the coarser (>2 mm) fraction. The difference between the yield in fine and coarse fractions was larger in the area where the drying of surface peat layer was severe. The difference was extremely large in the western part of the peatland (B8-13). This may be because the wax and / or resin components are relatively stable among the plant components, and therefore, they are concentrated when plant residues undergo decomposition. Thus, organic constituents were shown to be good indicators reflecting the change in environment and vegetation in the peatland.

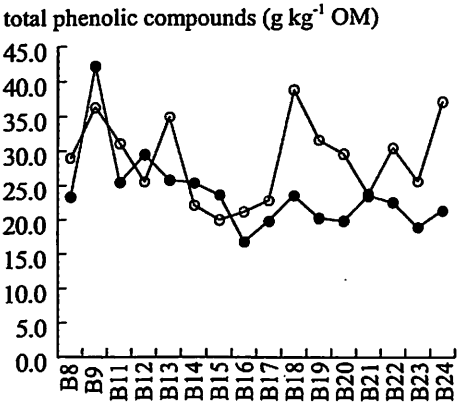

Figure 2 Yield of total phenolic compounds after CuO-NaOH oxidation of the peat.

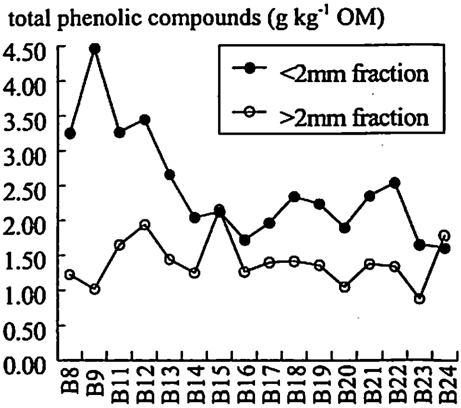

Figure 3. Yield of total long chain fatty acids (C14-C30) from the peat.

Acknowledgments: Special thanks are due to Drs. Y.Miyazaki, T.Kasubuchi, H.Ohtsuka, N.Miyaji, K.Kohyama, S.Itoh, K.Kimiwada of Hokkaido Agricultural Experiment Station, for allowing us to survey the mire and collect peat samples as well as for providing valuable information.

References

Crum, H. 1991. *A focus on peatlands and peat mosses.* The Univ. of Michigan Press.

Kaila, A. 1956. Determination of degree of humification in peat samples. *Journal of Agricultural Science Finland,* **28,** 18 - 35.

Kasubuchi, T., Miyaji, N., Kohyama, K., and Yanagiya, S. 1994. The water conditions of Bibai wetland and the investigation of its conservation method. *Japanese Journal of Soil Science and Plant Nutrition,* **65,** 326-333

Miyaji, N., Kohyama, K. and Ohtsuka, H. 1995. Evaluation of peatland in northern Japan in terms of land subsidence. *JARQ* , **29,** 95 - 102.

Tsutsuki, K., Esaki, I., and Kuwatsuka, S. 1994. CuO-oxidation products of peat as a key to the paleo-environmental changes in a wetland. *Soil Science and Plant Nutrition,* **40,** 107 - 116.

Tsutsuki, K. and Kondo, R. 1997. Change in fatty acid composition with age and environment in different types of peat profiles in Japan. *Soil Science and Plant Nutrition,* **43,** 285-294.

USDA 1984. Procedures for collecting soil samples and methods of analysis for soil survey. In: *Soil Survey Investigation Report No.1.* pp. 65-66. Soil Conservation Service, Washington D.C.

Understanding and Managing Organic Matter in Soils, Sediments, and Waters.
R.S. Swift and K.M. Spark (Eds)

Organic matter composition of peat as related to drying and vegetation change in a high-moor peatland

Kiyoshi Tsutsuki and Renzo Kondo

Laboratory of Land Resource Science, Obihiro University of Agriculture and Veterinary Medicine, Inada-cho, Obihiro, 080-8555 Japan.

Abstract

The composition of organic matter in the peat soil was investigated to clarify the effect of drying and vegetation change in a high-moor peatland at Bibai, Hokkaido, Japan. Yields of p-hydroxyphenyl compounds and vanillyl compounds were larger at the sites of *Sphagnum* community, while those of syringyl and cinnamyl compounds were larger at the sites of *Sasa senanensis* community. The yields of p-hydroxyphenyl compounds and vanillyl compounds were also larger in the finer (< 2 mm) peat fractions, while those of cinnamyl compounds were larger in coarser fractions (> 2 mm). Composition of fatty acids in peat was bimodal, peaking at palmitic acid and at lignoceric / cerotic acid. Total yield of fatty acid was larger in the finer peat fraction as well as at the sites where the peat was severely oxidised. β-Sitosterol, campesterol, and stigmasterol were more abundant in the coarse fraction than in the fine fraction as well as at the sites with dense *Sasa senanensis* vegetation than at *Sphagnum* vegetation.

Key words: Capillary gas chromatography, CuO-NaOH oxidation, fatty acid composition, lignin, phenolic compounds, sterol

Introduction

The development of drainage system in the surrounding agricultural field caused severe changes in hydrology and vegetation in a high-moor peatland at Bibai, Hokkaido, Japan. Such environmental change in peatland accompanied the changes in fundamental properties of peat, such as carbon and nitrogen contents, C/N, ash contents, fiber contents and bulk density as well as the changes in degrees of humification and decomposition of peat (Kondo and Tsutsuki 2001). In the present study, the detailed compositions of phenolic compounds, fatty acids, and sterols in peat were analysed further because they are important constituents of plants and are relatively stable under anaerobic condition which prevails in peat soils. Therefore, we have assumed that the composition of organic constituents in peat also reflects the changes in vegetation and hydrology in a peatland.

Materials and methods

Peat samples were the same as those used in the previous paper (Kondo and Tsutsuki 2001). Peat samples were separated to coarse and fine fractions using a 2-mm sieve. Phenolic compounds were liberated from peat sample by CuO-NaOH