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PREDICTING ENERGY CONTENT OF IN SITU PEATS BY MEANS OF THEIR MOISTURE CONTENT AND BULK DENSITY

LUONNONTILAISTEN TURVEKERROSTUMIEN ENERGIASISÄLLÖN ENNUSTAMISESTA TURPEEN VESIPITOISUUDEN JA TILAVUUSPAINON PERUSTEELLA

1. INTRODUCTION

The studies by Salmi (1947, 1949, 1954, 1961) showed that the calorific value of peat clearly increases with humification, but is also determined by the ash content and peat type. Salmi's material consisted of 300 peat samples obtained from different peatlands in western Finland. Because only the averages for each peat type in different degrees of decomposition were given in his publications, statistical relationships between these properties and the calorific value of peat remained open.

Mäkilä (1980) found a highly significant positive correlation between the degree of humification (v. Post) and the gross calorific value for samples (r = 0.508, n = 491) from Toholampi area, W. Finland (Ostrobothnia). For sedge peats the corresponding correlation in his material was barely significant (r = 0.220).

Highly significant correlations between the gross calorific value of *Sphagnum* peat and three different measures of the degree of decomposition (v. Post's, Pyavchenko's and Overbeck & Schneider's method) were reported by Pakarinen & Tolonen (1971), but linear correlations (r) between any of these measures and the heat value did not exceed 0.700. The electron paramagnetic resonance (EPR) was found to give good information about the heating value of peat samples (r = 0.927, n = 43) (Pohjola et al. 1980), whereas the five other methods in the same study for determining the degree of decomposition revealed weaker correlations with the heat value. Unfortunately the instruments needed for EPR measurements are very expensive and fairly rare so far.

During the past few years the procedure of taking peat samples in the field more or less precisely for their volume and simultaneously for water content have become more common (e.g. Tolonen & Saarenmaa 1979, Korpijaakko *et. al.* 1981 and literature therein). From the moisture content of peat strata an accurate evaluation of the dry matter content of peat layers below the water table can be done. This is shown, both for raised bog and aapa fen deposits, for example by Samsonova *et al.* (1954, 115, Boelter 1979 p. 608, Tolonen (1980), Tolonen *et al.* (1981) and Korpijaakko *et al.* (1981). Furthermore, advanced electronic methods for mesuring very rapidly the moisture content of peat seem promising (Varteva 1981).

In this preliminary report some non-systematically collected data will be presented showing the relationships between the *in situ* moisture content and bulk density values of peat and its calorific value. The working hypothesis comes from the fact that below the water table in peatlands the pore volume is chiefly filled by water, while on the other hand the total porosity and the quantity of water in peat are closely related to the bulk density and to the humification of peat (e.g. Boelter 1969, Päivänen 1969, 1973).

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2. MATERIAL AND METHODS

Our data come from undrained (virgin) peatlands in the U.S.A., Canada and Finland. In addition results are presented from three drained peat deposits in Finland. All the peat data from Maine, U.S.A., were picked up from the tables in Davis *et al.* (1980). Their samples were collected by manually operated peat samplers with MacCauley auger which is identical with the Russian peat sampler (Jowsey 1966, Day *et al.* 1979) and with Davis piston sampler (Bastin *et al.* 1909). For samples from Great Heath bog (Maine) the Davis sampler was employed C. Cameron pers. comm.). The samples were stored in the field in tight plastic bags and all the laboratory analyses performed in the U.S. Geological Survey laboratories in Pittsburg in accordance with ASTM (1969) standards.

The same ASTM standards were applied to the caloric determinations of the Canadian peats carried out at the Department of Natural Resources, Government of New Brunswick. Those peats were obtained by means of the Finnish piston sampler (see Tolonen 1968) in 1978 and 1979.

The energy contents of the Finnish peats used in this paper were analysed according to DIN standard (51900) in the State Fuel Centre (Vapo) in Jyväskylä. The carbon contents for the peats from Kaurastensuo bog and three aapa mires were determined at Lammi Biological Station, University of Helsinki by a new method using infrared CO_2-analyzer (Salonen 1979). The median variation (with 95 confidence limits) of 91 samples was 2.0 % (1.4—3.1 %). Four to six replicates were analysed from each sample. All the Finnish peats were taken with an open steel cylinder, 12 cm in diameter, or by large Russian peat sampler (10 cm in diameter, see Tolonen 1968). It might be stressed here that no special attention was put to retain the original water when taking the cores in field, nor in subsampling the 1 m long peat cores within two days in the laboratory for moisture content analysis.

For measuring the degree of decomposition the following methods were used: v. Post's squeezing method (v. Post 1922, see also Scott *et al.* 1980), centrifuge method according to the Soviet GOST standard (A19: 10650-72, see Anonymous 1976), the fiber content (Sneddon et al. 1971), the laboratory volume weight by Pyavchenko (1958) and the colorimetric method (Bascomb *et al.* 1977: 135). The number of replicates in those analyses was in accordance with the recommendations of the original instructions, being usually three in the other export in the centrifuge method where it was five. The moisture contents are expressed on dry weight (105°C) basis (water % per unit dry wt of peat = 100 · water of wet wt/100 — % water of wet wt).

The energy contents are expressed as BTU/lb (1 BTU = 1054.5 joules = 252.16 cal). Hence, the conversion coefficient from BTU/lb to kcal/kg is 0.5554 and from BTU/lb to MJ/kg 0.00232.

3. RESULTS

U.S.A.

In Fig. 1 the calorific values of 67 peat samples from the raised bog Great Heath in Maine, U.S.A. (Davis *et al.* 1980, Table 5) are plotted against their moisture contents. Three strongly deviating samples (nos 8, 35 and 64) were omitted from the consideration because of apparent errors in their water contents. The samples different depths from 0.75 to 8 m. The highest hummocks on Great Heath are about 0.6—0.7 m above the water table and thus all the material originates from depths below that level. Fourteen of the samples belong to sedge peats (black dots in Fig. 1) and the remaining to *Sphagnum* peats. According to our own field studies most of the *Sphagnum* peats in the Great Heath basin belongs to *Sphagnum* sectio *acutifolia.*

Table 1. Linear regression equations (y = bx + a) for ash-free gross calorifig value (BTU/lb) vs. degree of humification by v. Post's method (H_{1-10}) in some peatlands of New Brunswick, Canada. n = number of samples.

Taul. 1. Kalorimetrisen tuhkattoman lämpöarvon (y = BTU/lb) lineaariset regressioyhtälöt (y = b · x + a), kun x = maatumisaste v. Postin asteikossa eräillä New Brunswickin soilla, Kanadassa. n = näytteiden lukumäärä.

Mire No *Suo n:o*	b	a	r	R^2 %	n
		Year 1979 vuosi			
17N	418.6	6774.3	0.618	38.2	6
27	463.6	6744.5	0.733	53.7	8
36	35.9	9679.8	0.072	5.2	5
54	376.6	7389.6	0.601	36.1	8
60	192.7	8447.8	0.731	53.5	9
242	450.3	7077.1	0.936	87.6	7
271	62.9	8952.9	0.242	5.9	8
		Year 1978 vuosi			
496	465.6	6975.0	0.705	49.7	6
503	181.9	7829.1	0.860	73.9	7
504	194.0	6990.9	0.561	31.5	17
532	120.4	7279.0	0.536	28.7	7
568	159.7	7444.9	0.556	30.5	8
10	441.4	6746.8	0.773	59.7	11
4	373.6	6842.0	0.906	82.0	12.0
305	493.2	6364.3	0.895	80.0	17
324	231.8	7129.4	0.420	17.6	13
1978 + 79 All peat	333.8	7038.2	0.528	27.8	164
1978 + 79 Sphagnum peats	281.2	7101.4	0.620	38.4	118
1978 + 79 Carex peats	270.7	8074.2	0.459	21.0	47
1979 Sphagnum peats	310.5	7373.8	0.697	48.6	41
1979 Carex peats	215.4	8895.0	0.360	13.0	20

A highly significant negative correlation (r = —0.824, n = 67) was obtained between *in situ* moisture content and calorific value. Because the ash content of Great Heath peats is fairly low, mostly less than 2.0 %, the corresponding equation for ash corrected peats did not yield a higher corre-

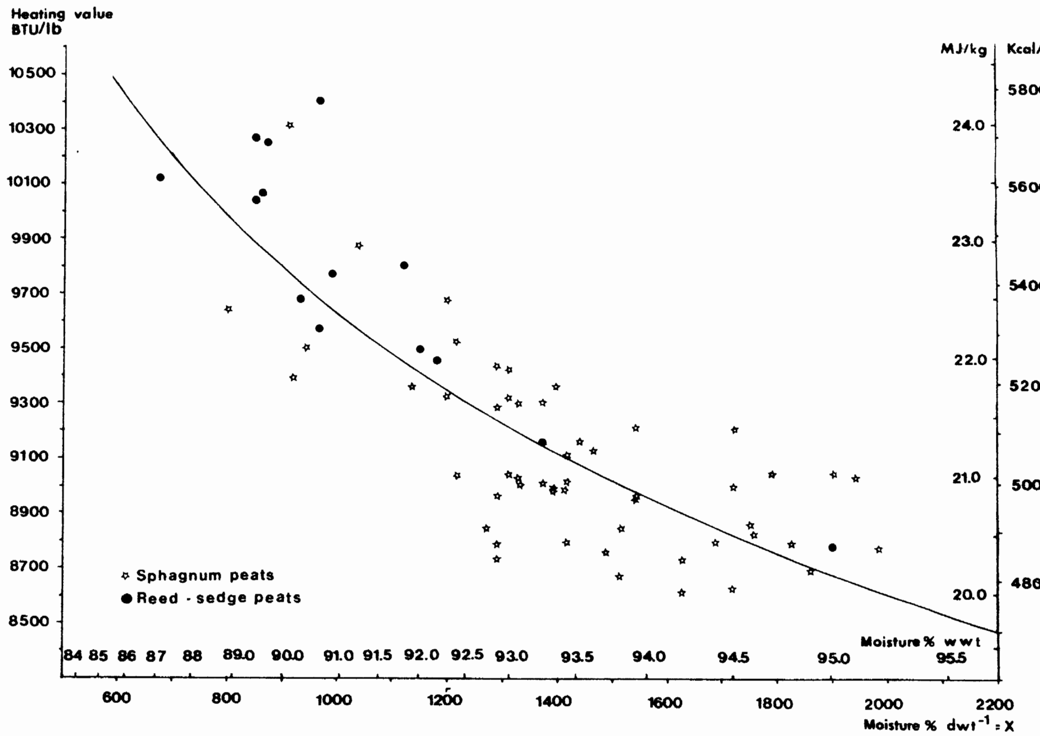

Fig. 1. Great Heath, Maine, U.S.A. Water-free gross calorific value BTU/lb (without ash correction) vs. moisture per cent of dry weight. lny = —0.161 lnx + 10.287 (r = —0.824, n = 67). Material from Davis *et al.* (1980 Table 5).

Kuva 1. Great Heath -keidassuo, Maine, U.S.A. Vedettömän kalorimetrisen lämpöarvon riippuvuus turpeen maastokosteudesta.

lation than that in Fig. 1.

We also calculated the linear regression between the carbon content and gross calorific value of peats using Great Heath data (Davis *et al.* Table 5). The result was

$$y = 203.15 x — 1986.8, r = 0.921, n = 70$$

where y = calorific value BTU/lb dry weight
x = carbon content of peat per dry weight

This supports the evidence that both the carbon and calorific value analyses from Great Heath were correct. Unfortunately there were no information available about the degree of decomposition for the Great Heath peats by any methods.

Canada

Data from 22 Canadian peatlands (from New Brunswick) have been presented in Table 1 showing relationships between calorific value and humification (v. Post method) as well as heating value and moisture content *in situ*. The former regression was of linear form, while the ''power curve'' of the same form as in Great Heath was found to result in the best fit for the latter. Surface samples above the water table were excluded. Because the samples were not collected in order to retain their water content, a few samples (4 from 168), which apparently had lost considerably water before laboratory, were omitted.

The number of samples within individual core profiles may be too low to produce reliable regression equations for any of the peatlands. Nevertheless, a common feature is that both the degree of humification (v. Post) and the moisture content have a fairly high correlation (r over 0.9) with the calorific value, when the individual peatlands are considered.

In the total material (n = 164), the correlation between moisture content and gross calorific value was r = —0.688 (R^2 = 42 %), but between v. Post's humification degree and calorific value clearly lower: r = 0.528 (R^2 = 28 %). For *Sphagnum* peats from 1979 the corresponding correlation coeffi-

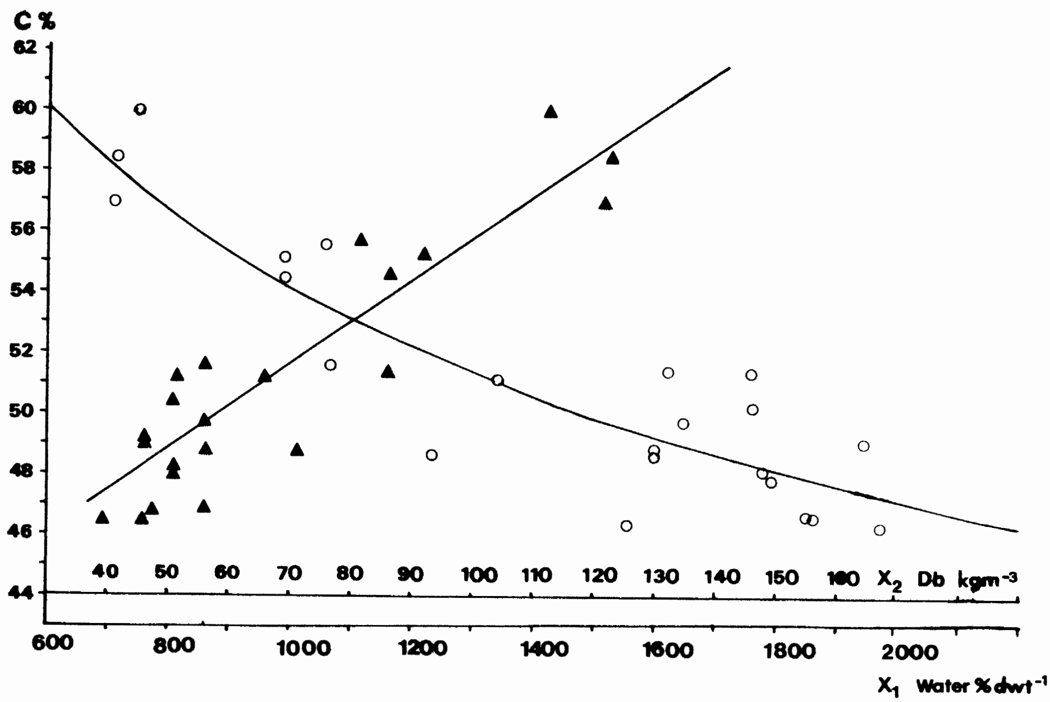

Fig. 2. Raised bog Kaurastensuo, Lammi, S. Finland. Ash-free carbon content vs. moisture per cent of dry weight (X_1 = circles) and vs. dry bulk density (X_2 = triangles). The regression equations were $\ln y = -0.202 \ln x_1 + 5.389$, $r = -0.874$ ($r^2 = 76.5$ %) and $y = 0.143 \cdot x_2 + 41.4$, $r = 0.904$ ($r^2 = 81.7$ %).

Kuva 2. Kaurastensuo, Lammi. Turpeen tuhkattoman hiilipitoisuuden riippuvuus turpeen kosteudesta (X_1 = renkaat) ja kuivatilavuuspainosta (X_2 = kolmiot).

cients were $r = -0.795$ (moisture) and $r = 0.697$ (v. Post). In *Carex* peats both correlations were much weaker, even if still statistically significant ($p < 0.001$).

Finland

Raised bogs. From a peat core of raised bog Kaurastensuo, (Lammi, S Finland) carbon analyses are available from every second of the successive 10 cm samples. When plotted against their bulk density values a highly significant (P 0.001) linear relationship was obvious (Fig. 2):

$$y = 0.143 x + 41.392, \quad r = 0.904 \; (n = 22)$$

where y = carbon content per OM

x = bulk density of peat g cm^{-3} (= kg m^{-3}).

The correlation between the moisture content and carbon content was of the same form above in American peats the correlation between moisture and calorific value. The correlation coefficient was $r = -0.874$. Also the degree of decomposition of Kaurastensuo peats by v. Post method had a fairly high linear correlation with carbon content ($r = 0.841$). Very similar relationships between the calorific values of peat and the bulk density and moisture content were found from raised bog Varrassuo in Hollola, S Finland (see Pohjola *et al.* 1980). In addition, some other methods used for measuring the degree of decomposition are included in Table 2 in form of regression equations.

Aapa mires (fens). Two attempts were made to examine which kinds of relationships can be found in peat strata, exclusively consisting of sedge and *Bryales* dominated peats, between the energy content and different measures of the humification and the moisture content. The material is from one deep profile of the virgin part of mire Suolamminneva, Ähtäri, Middle Finland and from one deep profile from Puohtiinsuo, Ilomantsi, Eastern Finland (Table 3). The linear correlation coefficients resulting, did not exceed $r = 0.600$ in any case but were mostly as low as 0.200. Water content and bulk density were among the weakest explanators

Table 2. Regression equations for ash-free gross caloritic value (BTU/lb) vs. moisture content of peat (% of dry weight) in some peatlands of New Brunswick, Canada. Regressions are of form lny = b · lnx + a. More accurately in text. n = number of samples.

Taul. 2. Kalorimetrisen tuhkattoman lämpöarvon (BTU/lb) riippuvuus turpeen maastokosteudesta (vesipit. % kuivapainosta) eräillä New Brunswickin soilla. Yhtälöt ovat muotoa lny = b ·lnx + a. n = näytteiden lukumäärä.

Mire No *Suo N:o*	b	a	r	R^2 %	n
	Year 1979 vuosi				
17N	—0.285	11.16	—0.659	43.4	6
27	—0.341	11.52	—0.936	87.6	8
36	—0.561	13.04	—0.852	72.6	5
54	—0.298	11.22	—0.911	83.0	8
60	—0.241	10.82	—0.675	45.6	9
242	—0.478	12.46	—0.962	92.5	7
271	—0.425	12.05	—0.964	92.0	8
	Year 1978 vuosi				
496	—0.442	12.14	—0.911	83.0	6
503	—0.216	10.57	—0.777	60.0	7
504	—0.227	10.57	—0.625	39.0	17
532	—0.284	10.97	—0.768	58.9	7
568	—0.171	10.23	—0.830	69.0	8
10	—0.322	11.27	—0.806	65.0	11
4	—0.292	11.09	—0.720	51.9	12
305	—0.287	11.05	—0.806	65.0	7
324	—0.202	10.43	—0.590	34.8	13
78 + 79 All peats	—0.294	11.12	—0.688	47.3	164
78 + 79 Sphagnum peats	—0.248	11.78	—0.651	42.4	118
78 + 79 Carex peats	—0.218	10.64	—0.379	14.4	47
79 Sphagnum peats	—0.297	11.181	—0.795	63.2	41
79 Carex peats	—0.091	9.843	—0.091	2.1	20

of the energy content.

In agreement with the weak correlation between calorific value and bulk density in sedge fens, we also obtained similar results regarding the carbon content in peat layers of virgin aapa mires. The material is from Silmäsvuoma, Kittilä, Takasuo, Ylikiiminki and Suurisuo, Janakkala. In all three cases linear solution resulted in the best fit in the regression between the carbon content and bulk density (dry), but the correlation coefficients remained low being as follows:

Silmäsvuoma, r = 0.529 (n = 17)
Takasuo, r = 0.476 (n = 24)
Suurisuo r = 0.073 (n = 30)

Our interpretation, which is based on field observations, is that in minerotrophic wet sedge fen peats the occurrence of water

Table 3. Raised bog Varrassuo, Hollola, Finland. Regression equations between the ash-free gross caloritic value (BTU/lb) and different variables (X_1—X_9):

X_1 = moisture content % of dry weight — *kosteussadannes kuivapainosta*
X_2 = bulk density kg m^{-3} — *"todellinen" turpeen tilavuuspaino suossa kg m^{-3}*
X_3 = electron paramagnetic resonance (EPR) see Pohjola *et al.* (1980) — *elektronien paramagneettinen resonanssi (EPR) katso Pohjola ja muut (1980)*
X_4 = degree of humification by v. Post's method (H_{1-10}) — *maatumisaste v. Postin asteikossa*
X_5 = unrubbed fiber content (% dwt^{-1}) — *kuituisuussadannes kuivapainosta*
X_2 = per cent of decomposition by centrifuge (GOST) method — *maatumissadannes sentrifugimenetelmällä*
X_7 = per cent of decomposition by Pyavchenkos method — *maatumissadannes Pjavtshenkon menetelmällä*
X_8 = per cent of decomposition by colorimetric (Bascomb *et al.)* method — *maatumissadannes kalorimetrisellä menetelmällä*
X_9 = per cent of ash of dry weight — *tuhkasadannes kuivapainosta*

Taul. 3. Varrassuo, Hollola. Tuhkattoman kalorimetrisen lämpöarvon (BTU/lb) riippuvuus eräistä mitatuista turpeen ominaisuuksista.

Muuttujan X_1 yhtälö oli muotoa lny = b ·lnx + a, kaikki muut yhtälöt olivat lineaarisia (y = bx + a). n = näytteiden lukumäärä.

Variable — *Muuttuja*	b	a	r	R^2 %	n
X_1	— 0.235	10.760	—0.807	65.1	43
X_2	21.464	7371.88	0.841	70.7	43
X_3	37.61	7763.40	0.927	85.9	41
X_4	295.37	7447.12	0.848	71.9	43
X_5	—13.818	10174.65	—0.405	16.4	43
X_6	54.20	7717.92	0.628	39.4	43
X_7	29.18	8202.59	0.660	43.6	43
X_8	38.58	7837.92	0.748	55.9	19
X_9	—176.91	9390.45	—0.192	3.7	37

is of greatly different form than in ombrotrophic raised bog peats. There are numerous water pockets and veins in slightly to moderately decomposed sedge peats.

In *Sphagnum* peats, the primary total pore volume greatly decreases within the decomposition process. The anatomic structure of the aapa fen plants (sedges, grasses, herbs and brown mosses) results in a much smaller initial porosity than has been found in *Sphagnum* peats. Therefore neither the water content nor the bulk density, which is closely correlated with it, could predict the real degree of decomposition and consequently the energy content in fen peats.

Drained peatlands. As a natural consequence of draining the bulk density of peat increases due to the com-

Table 4. Two practically natural sedge mire sites in Finland, Puohtiinsuo, Ilomantsi (site A in Tolonen 1963) and Suolamminneva, site 5 C, Ähtäri. Regression between gross caloritic value (y, BTU/lb) and five different variables. X_1 = moisture content per dry weight (%), X_2 = bulk density kg m^{-3}, X_3 = degree of humification (v. Post), X_4 = unrubbed fiber content (%), X_5 = colorimetric humification percentage. n = 20 in all the analyses of Puohtiinsuo and 26 in those of Suolamminneva.

Taul. 4. Tulokset kahdesta käytännöllisesti katsoen luonnontilaisesta sarasuokerrostumasta Ilomantsin Puohtiinsuosta ja Ähtärin Suolamminnevan pisteestä 5 C. Lämpöarvon (BTU/lb) riippuvuus viidestä eri muuttujasta. X_1 = kuivapainokosteussadannes, X_2 = tilavuuspaino kg m^{-3}, X_3 = v. Postin maatumisluokka, X_4 = jauhamaton kuituisuussadannes, X_5 = kolorimetrinen maatumissadannes. Näytteitä 20 kaikissa Puohtiinsuon ja 26 kaikissa Suolamminnevan määrityksissä.

Mire Puohtiinsuo		r	R^2 %
lny = 0.236	ln X_1 + 7.514	0.387	15.0
lny = 0.231	ln X_2 + 8.235	0.519	26.9
y = 252.42	X_3 + 8081	0.432	18.7
y = —49.87	X_4 + 11720	—0.510	26.0
y = 29.71	X_5 + 8365	0.329	10.8
Mire Suolamminneva 5 C		**5**	**R^2 %**
lny = —0.0508	lnx_1 + 9.502	—0.380	14.4
lny = 0.0554	lnx_2 + 8.905	0.561	31.5
y = 158.67	x_3 + 8594	0.402	16.2
y = —13.24	x_4 + 10002	—0.535	28.6
y = 3.212	x_5 + 9027	0.341	11.6

paction (both compression and creep). It follows that neither bulk density nor water content of peat can tell very much about the degree of decomposition and energy content in drained peat deposits. In agreement with this theory we found in the drained marginal area of mire Suolamminneva, Ähtäri a very weak correlation between energy content (BTU/lb) and water content (r = 0.294, n = 14) and between energy content and bulk density (r = 0.119, n = 14).

Correspondingly in a very old drainage of a small bog in Pukkila, Muurla, southwestern Finland correlation between carbon content and water content (of dry weight) was r = —0.158 (n = 20) and between carbon content and bulk density r = 0.161 (n = 20), respectively.

In a drained peatland in N. Finland, Kaivosneva in Pulkkila, Toivonen (1980) reported a linear correlation coefficient r = 0.379 (n = 51) for the regression of calorimetric heat value vs. bulk density.

4. Conclusions

Our preliminary results suggest that in undrained raised bogs, the energy content of peat can be estimated within a fairly small degree of risk by means of moisture content. In the same type of peat strata, all the conventional methods used for determining the degree of humification were weaker explanators for the variation in the energy content.

It seems reasonable for us to estimate that the prediction of the energy content of *in situ* peats of natural state by means of moisture content or bulk density can be made by a precision up to 80 % or even higher, if the moisture content has been precisily determined. The primary differences in the calorific values of different peat forming plant species (e.g. Cummins & Wuychek 1971, Sylvester & Wein 1979 are responsible for the rest of the variation. In very wet sedge and brown-moss peats of aapa fens close relationships hardly exist between the moisture and energy content. In those peats the conventional methods for estimating the degree of decomposition or heating value were very weak, as well. Further work is needed to examine, whether in sedge peats and related materials the EPR analyses (Pohjola *et al.* 1980) or carbon analyses or several methods together can be successfully applied instead of laborious, slow and expensive calorimetric analyses.

In drained peat deposits there were weak relationships between energy (or carbon) content and water content as well as between energy content and bulk density.

REFERENCES

American Society for Testing and Materials 1969: Standard D 2607—69. Standard classification of peats, mosses, humus and related products. — American Society for Testing and Materials. Philadelphia. Pa.

Anonymous 1976: The state standard of the USSR. Peat. Method of the determination of the degree of decomposition. — Transactions of the Working Group for Classification of Peat. International Peat Society Commision 1, 59—66. Helsinki.

Bascomb, C.L., Banfield, C.F. & Burton, R.G.O. 1977: Characterisation of peat material from organic soils (histosoils) in England and Wales. — Geoderma 19, 131—147.

Bastin, E.S. & Davis, C.A. 1909: Peat deposits of Maine. — U.S. Geol. Survey Bull. 376, 125 pp.

Boelter, D.H. 1969: Physical properties of peats as related to degree of decomposition. — Soil Sci. Amer. Proc. Vol. 33, 606—609.

Cummins, K.W. & Wuychek, I.C. 1971: Caloric equivalents for investigations in ecological energetics. — Mitt. int. Ver. Limnol. 18, 1—158.

Davis, J., Anderson, W. & Cameron, C. 1980: Peat resource evaluation. State of Maine. Peat Program. Final report: phase one July 1980. — 17 pp + 7 Tables. U.S. Dept. of Energy, Office of Fossil Energy.

Day, I.H., Rennie, P.J., Stanek, W. & Raymond, G.P. (eds.) 1979: Peat testing manual. National Res. Counc. Canada Ass. Comm. on Geotechn. Res. Techn. Mem. 125, 1—193. —

Jowsey, P.C. 1966: An improved peat sampler. — New Phytol. 65 (2), 245—248.

Korpijaakko, M., Häikiö, J. & Leino, J. 1981: Vesipitoisuuden ja maatuneisuuden vaikutus turpeen kuivatilavuuspainoon. (Summary: Effect of water content and degree of humification on dry density of peat.) — Suo 32, 39—43.

Mäkilä, M. 1980: Tutkimus Toholammin turvevarojen käyttökelpoisuudesta ja turpeen eri ominaisuuksien välisistä riippuvuuksista. (Summary: The peat resources of Toholampi municipality and their potential use both correlations between different peat factors.) — Geol. tutkimuslaitos, maaperäosasto, Raportti P 13.6/8015, 1—137.

Overbeck, F. & Schneider, S. 1940: Torfzersetzung und Grenzhorizont, ein Beitraz zur Frage der Hochmoorentwicklung in Niedersachsen. — Angew. Botanik 22 (5), 321—379.

Päivänen, J. 1969: The bulk density of peat and its determination. — Silva Fenn. 3, 1—19.

Päivänen, J. 1973: Hydraulic conductivity and water retention in peat spils. — Acta For. Fenn. 129, 1—70.

Pakarinen, P. & Tolonen, K. 1971: Rahkaturpeen maatumisasteen määritysmenetelmistä. (Summary: Comparison between some methods of determining the degree of decomposition of Sphagnum peat.) — Suo 22, 48—50.

Pohjola, P., Eloranta, J., Nyrönen, T. & Tolonen, K. 1980: On the determination of the degree of humification of peat. An application of the electron paramagnetic resonance (EPR) spectroscopy. — Proc. 6th Int. Peat Congress, Duluth, Minnesota, U.S.A., August 17—23, 1980, pp. 649—654.

Post. L. von 1922: Sveriges geologiska undersökninges torvinventering och några av dess hittils vunna resultat. — Sv. Mosskulturför. Tidsskrift 1, 1—27.

Pyavchenko, N.J. 1958: Metod opredelenija stepeni razlozhenija torfa po objemnomy vesy. (Determining the humification degree on the basis of volume weight.) — Moskva 11 pp.

Scott, I.B., Korpijaakko, E.O. & Tibbetts, T.E. 1980: Development of conversion factors for expressing peat resource estimates. — Symposium Papers, Peat as an Energy. Alternative Arhington, Virginia U.S.A. December 1—3, 1980, 37—49. Institute of Gas Technology.

Salonen, K. 1979: A versatile method for the rapid and accurate determination of carbon by high temperature combustion. — Limnol. Oceanogr. 24, 177—183.

Salmi, M. 1947: Turpeiden tuhkapitoisuuksista ja lämpöarvoista. (The heat value and percentage of ash in peat.) — Tekn. Aikak. lehti 4, 151—153.

Salmi, M. 1949: Physical and chemical peat investigations on the Pinomäensuo bog, SW Finland. — Bull. Comm. géol. Finl. 145, 1—31.

Salmi, M. 1954: Investigation of the caloric values of peats in Finland. — 1st Int. Peat Congress Dublin, Ireland, July 1954, Section B3, 9 pp.

Salmi, M. 1961: Turve ja sen käyttö. — Geol. tutkimuslaitos, Geotekn. Julk 65, 52—62.

Samsonova, N.N., Belekopytova, I.E. & Varenzova, V.S. 1954: Spravotšnik po torfu. (Handbook of peat.) — Gosenergoizdat, 722 pp. Moskva—Leningrad.

Sneddon, J.I., Farstad, L. & Lackulich, L.M. 1971: Fiber content determination and the expression of results in organic soils. — Can. J. Soil. Sci 51: 138—141.

Sylvester, T.W. & Wein, R.W. 1979: Fuel characteristic of arctic plant species and simulated plant community flammability by Rothermel's model. — Canadian J. Bot. 59, 898—907.

Toivonen, T. 1980: Turpeen tilavuuspainon ja eräiden muiden fysikaalis-kemiallisten ominaisuuksien merkityksestä sekä suon energiasisällön laskemisesta Pulkkilan Kaivosnevalla. (Summary: The significance of the bulk density and some other physico-chemical properties of peat, and the calculation of the energy content of the mire Kaivosneva, Pulkkila.) — Pro gradu -tutkielma. Turun yliopiston geologian ja maantieteen laitos, Maaperägeologia, Joulukuu 1980, 75 s. (M.Sc. thesis, 75 p. University of Turku, Finland, Dept. of Quaternary geology).

Tolonen, K. 1963: Ueber die Entwicklung eines nordkarelischen Moores im Lichte der C^{14} -Datierung. Das Moor Puohtiinsuo in Ilomantsi (Ost-Finnland). — Arch. Soc. "Vanamo" 18, 41—57.

Tolonen, K. 1968: Soiden kehityshistorian tutkimusmenetelmistä. II. Turvekairoista. (Summary: On methods used in studies of the peatland development. II. On the peat samplers.) — Suo 18, 86—92.

Tolonen, K. 1980: Turpeen tilavuuspainon riippuvuus vesipitoisuudesta. — Valmisteltu puheenvuoro Suo-seuran kokouksessa 22. 4. 1980. Julkaisematon. (Dependence of bulk density on the moisture content. Unpubl. Communication at the meeting of Finnish Peatland Society 24. 4. 1980).

Tolonen, K. & Saarenmaa, L. 1979: The relationship of bulk density to three different measures of the degree of peat humification. — Proc. Int. Symp. Classification of Peat and Peatlands. Hyytiälä, Finland. International Peat Society, Helsinki, 227—238.

Tolonen, K.H., Davis, R.B. & Gelinas, D.A. 1981: Peat accumulation in and landsat mapping of the peatlands of Maine. Progress report II. — 35 pp. + 4 Appendixes. Maine Geological Survey Dept. of Conservation and Department of Energy, Augusta, Maine, U.S.A.

Varteva, R. 1981: Tutka kertoo suon rakenteen. — Helsingin Sanomat no 237 (29813): 20. Helsinki.

Lyhennelmä:

LUONNONTILAISTEN TURVEKERROSTUMIEN ENERGIASISÄLLÖN ENNUSTAMISESTA TURPEEN VESIPITOISUUDEN JA TILAVUUSPAINON PERUSTEELLA

Polttoturvekäyttöön sopivat suot on vanhastaan totuttu rajaamaan maastossa suoritettujen turvelaji- ja maatumisastemääritysten perusteella. Niitä on täydennetty tuhkapitoisuus- ja lämpöarvomäärityksin laboratoriossa. Varsinkin viimeksi mainitut ovat kuitenkin suuritöisiä, hitaita ja kalliita (yksi määritys voi maksaa n. 650 mk). Edellä mainittujen turpeen ominaisuuksien osuutta Suomen soiden lämpöarvoihin selvitti 1940-luvun lopulta lähtien mm. Salmi (1947, 1949, 1954, 1961).

Myöhemmistä töistä, joissa myös tutkittiin miten suuri osa suon energiasisällön vaihtelusta voitiin turpeen maatumisasteella ennustaa, mainittakoon ennenkaikkea Mäkilän (1980) julkaisema. Hänen aineistonsa käsitti 481 näytettä Toholammilta. Vaikkakin sekä koko aineistossa että useimmissa turvelajiryhmissä löydettiin erittäin merkitsevä positiivinen riippuvuus v. Postin menetelmällä määritetyn maatumisasteen ja turpeen lämpöarvon välillä, selitysasteet jäivät suhteellisen alhaisiksi (kaikissa ryhmissäkin alle 50 %).

Tämän artikkelin kirjoittajat huomasivat Pohjois-Amerikan itäosien soilta kerätyssä aineistossa varsin selvän riippuvuussuhteen turpeen vesipitoisuuden ja energiasisällön välillä. Edellytyksenä oli, että näyte on ojittamattomalta suolta ja suopohjavesipinnan alapuolelta. Siellä turpeen veden määrä ilmeisesti mittaa turpeen todellista maatuneisuuden astetta: mitä maatuneempi turve, sitä pienempi huokostilavuus (mm. Boelter 1969, Päivänen 1969, 1973) ja sitä vähemmän vettä.

Valitettavasti tarkasteluumme ei ole käytettävissä varta vasten kosteussadanneksen tarkkaa määrittämistä varten kerättyä aineistoa. Mainen soilta kerätyt näytteet (Davis ja muut 1980) oli otettu noin 2.5 cm läpimittaisella Davis mäntäkairalla ja n. 4 cm läpimittaisella pienellä venäläisellä kairalla. Kanadan soilta näytteet oli otettu suomalaisella putkikairalla (läpim. 5 cm) ja toisena vuonna venäläisellä turvekairalla. Näistä puutteista huolimatta turpeen kosteuden havaittiin Great Heath-keidassuolla selittävän lähes 70 % lämpöarvon vaihtelusta (kuva 1). Samalla suolla turpeen hiilipitoisuus selitti 87 % lämpöarvon vaihtelusta, minkä tulkitsimme luotettavien määritysten todisteeksi. Yleensä näytti siltä, että turpeen vesipitoisuus ennusti lämpöarvoa hyvin Kanadan soilla, joissa von Postin nyrkkimenetelmän maatumisastekin teki saman (taulukot 1 ja 2). Ero näiden kahden ennustajan välille syntyi, kun eri soista kootut tiedostot yhdistettiin. Vesipitoisuus nousi tällöin selvästi paremmaksi lämpöarvon selittäjäksi kuin v. Postin maatumisaste.

Suomalaisessa aineistossa huomattiin rahkaturpeiden lämpöarvon ja hiilipitoisuuden olevan tiukassa riippuvuussuhteessa turpeen maastokosteuteen (kuva 2, taul. 3). Vähintäänkin tämä riippuvuus lienee suuruusluokkaa n. 80 % kokonaisvaihtelusta, sillä kotoisiltakaan rahkasoiltamme ei käytettävissämme ollut veden suhteen huolella kerättyjä näytteitä. Siitä huolimatta meikäläisissäkin aineistossa vesipitoisuus ja kuivatilavuuspaino selvisivät voittajina vertailussa erilaisiin kenttä- ja laboratoriomenetelmiin, joita on kehitetty maatumisasteiden määrittämiseen (taulukko 3).

Päinvastoin kuin rahkasoissa, ei vesipitoisuus eikä tilavuuspaino ainakaan esimerkkinä olleissa märissä saroissamme pystyneet ennustamaan missään määrin luotettavasti suon energiapitoisuutta. Mutta eivät siihen pystyneet myöskään muut käytetyistä menetelmistä (taulukko 4). Tämän katsoimme johtuvan veden erilaisesta esiintymistavasta märissä aapasoissamme (vesitaskut, vesisuonet jne.), joista meillä on kenttähavaintoja, mutta myös sara- ja rahkaturpeen muodostajakasvien erilaisesta anatomisesta rakenteesta.

Eri suokasvien alkuperäiset energiapitoisuuserot kuvastuvat eri turvelajien energiaeroina niinkuin Salmi (mm. 1961) on osoittanut. Tästä johtuen turpeen vesipitoisuudella tai tilavuuspainolla ei päästäne ennustamaan juurikaan yli 80 % turpeen lämpöarvosta edes rahkasoissa.

Ojitusta seuraava turpeen kokoonpuristuminen ja kuivuminen hävittää mahdollisuudet arvioida kerrostuman maatuneisuutta ja sitä kautta suon energiasisältöä vesipitoisuuden tai tilavuuspainon avulla. Tämä tuli selväksi sekä Ähtärin Suolamminnevalla ja Muurlan Pukkilan suolla että Toivosen (1980) aineistossa ojitetulta Pulkkilan Kaivosnevalta.

Kehitystyön alla olevat, mutta jo nyt lupaavia tuloksia antaneet sähköaaltotutkat suon vesipitoisuuden tarkaksi määräämiseksi maastossa (ks. Varteva 1981) loisivat edellytykset sekä turpeen määrän (vrt. mm. Tolonen et al. 1981, Korpijaakko 1981) että rahkasoissa ehkä myös laadun nopealle ja kustannuksiltaan erittäin alhaiselle arvioinnille. Jälkimmäinen tehtävä kuitenkin edellyttää edellä esittämiemme riippuvuussuhteiden yleispätevyyden selvittämistä.