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Acrotelm development on Raheenmore Bog (Ireland)

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Abstract

During the Irish-Dutch Raised Bog Project (1989-2001), a system of assessing the actual and potential ecohydrological conditions with acrotelm transmissivity as the central parameter was developed. In 1991-92 an acrotelm survey, including transmissivity measurements on Raheenmore Bog showed that conditions were considerably below the potential situation, based on the theoretical relationship of transmissivity with flow pattern and surface slope. The difference was attributed to internal drainage and peat cutting along the bog margins. The drains have been blocked around 1995 and occasional measurements in 1999-2002 suggested a positive acrotelm development. Hence Raheenmore Bog is a good environment to test the theory mentioned above, which would be relevant in modelling raised bog development, at least in the Atlantic climate zone of north-western Europe. To test the theory, the surveys of 1991/92 were repeated between November 2002 and April 2003. Some results are shown in this paper.

1. Introduction

Raheenmore Bog is a raised bog of about 100 ha in Co. Offaly, Ireland. In Irish Midland raised bogs the transmissivity of the catotelm is generally very low, with values around 1 m^2d^{-1}. However, the transmissivity of the acrotelm can be up to several thousand m^2d^{-1} (Van der Schaaf, 2002). Hence the acrotelm is the bog's aquifer. The transmissivity behaviour of the acrotelm depends on processes of production and decay of organic material. Freshly produced material contains many large pores and has a large hydraulic conductivity, whereas the compaction and the amount of small particles increases with decay (humification), which results in much smaller pores.

Raheenmore Bog suffered from internal drainage in a considerable part of the bog and turf cutting along its margins. In 1991/92 results from acrotelm transmissivity measurements on Raheenmore Bog were compared to what they would be in an optimal situation (theory described in section 2). The comparison indicated a poor development of the acrotelm. In 1995 drains were blocked in an attempt to stimulate acrotelm growth. Occasional measurements in 1999-2002 showed a positive development and therefore the acrotelm transmissivity and thickness were investigated again in 2002/03. The results were compared with the theoretical relationship between transmissivity, surface slope and flow path and with the measurement of 1991/92. Data from 1991/92 were obtained from Van 't Hullenaar & Ten Kate (1991), Sijtsma & Veldhuizen (1992) and Van der Schaaf (1999). A levelling in 2002 showed only minor differences with the one of 1991. This justifies the comparison between both data sets.

2. Acrotelm transmissivity, surface slope and flow pattern

The acrotelm transmissivity can be written as a function of surface slope and flow pattern (Ivanov, 1965, 1972, 1981). The function can be derived from Darcy's law:

$$q_a = -T_a \frac{\mathrm{d}H}{\mathrm{d}s} \tag{1}$$

where

q_a : flux [L^2T^{-1}]

T_a : transmissivity of the acrotelm [L^2T^{-1}]

H : hydraulic head [L]

s : distance along a flow path [L]

The hydraulic gradient $\frac{\mathrm{d}H}{\mathrm{d}s}$ is approximately equal to the surface slope I [1] and Eq. 1 becomes:

$$q_a \approx -IT_a \tag{2}$$

The surface slope remains almost constant in time, which means a dependence of the transmissivity on discharge.

If a flow path with length L_u [L] and width w [L] (Figure 1) is considered, the discharge at the downstream part of the flow path is equal to the product of the upstream area A_u [L^2] and the specific discharge v_a [LT^{-1}]:

$$Q_a = A_u v_a \tag{3}$$

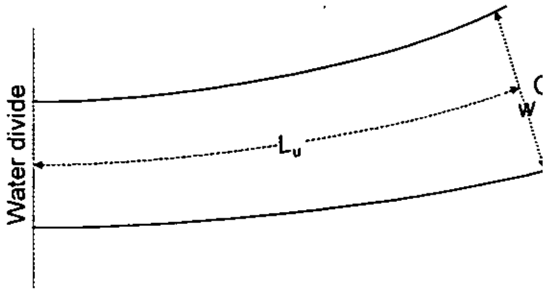

Figure 1. Flow path with upstream length L_u, width w and outgoing flux Q_L (Van der Schaaf, 2002)

The average flux across the line at distance L_u is found by dividing Eq. 3 by the path width w:

$$q_a = \frac{A_u v_a}{w} \tag{4}$$

Substituting Eq. (4) in Eq. (2) yields:

$$T_a \approx \frac{A_u v_a}{wI} \qquad (5)$$

Acrotelm transmissivity was measured on two perpendicular transects (as shown in Fig.2). Approximately square holes of 20 by 20cm were dug, the depth extending to below the acrotelm layer. With a low capacity pump of 0.5-10 l min^{-1} water was removed from a hole during a few minutes. Thus a draw-down of the water level was created and from it transmissivity was derived.

Eq. (5) yields the potential transmissivity of an acrotelm. With it, the condition of a bog can be evaluated by calculating a ratio between the calculated and the measured transmissivity ($T_{a\ \mathrm{calculated}}/T_{a\ \mathrm{measured}}$). A bog with a healthy acrotelm will yield ratios around 1; a disturbed bog will give much higher values.

In Table 1 the ratios per site are listed for both 1991/92 and 2002/03. Also the geometric mean for all the sites is given.

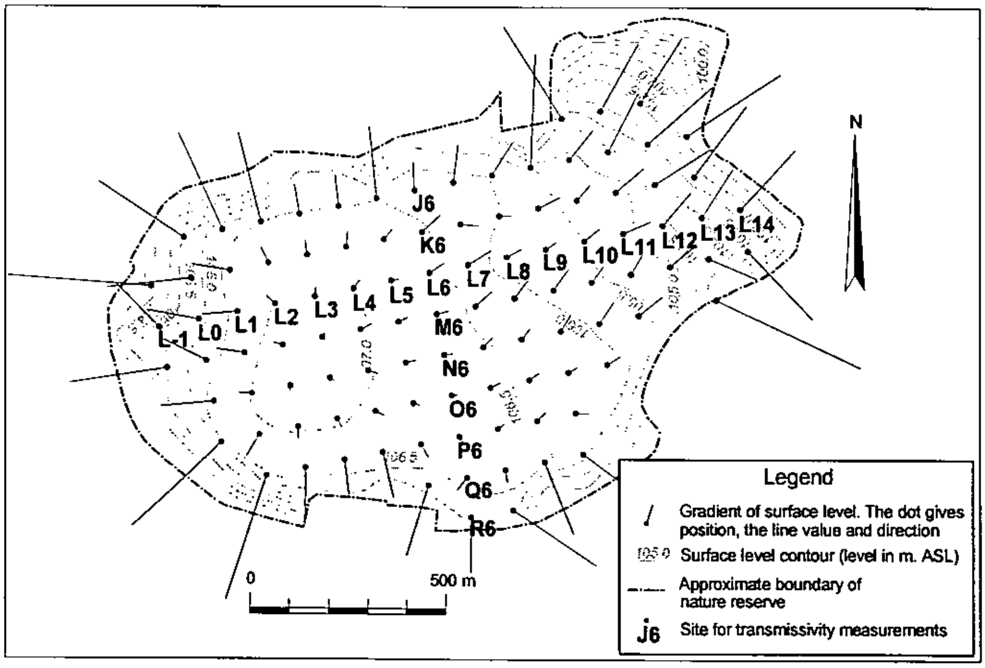

Figure 2. Raheenmore Bog with contour lines, slopes and measuring sites.

The averaged ratio in 2002/03 is closer to 1 than in 1991/92, indicating a positive development of the acrotelm in the last 10 years. Ratios less than 1 can exist due to microrelief in the surface, not representing the surface slope on a larger scale, (which was used for calculating the potential T_a), or because measuring sites were located on old drains, thus creating conditions with larger actual than potential transmissivities.

Table 1. Ratios of calculated and measured acrotelm transmissivity T_a

Site	$T_{calculated}/T_{measured}$ 1991/92	$T_{calculated}/T_{measured}$ 2002/03	Site	$T_{calculated}/T_{measured}$ 1991/92	$T_{calculated}/T_{measured}$ 2002/03
L-1	2.7	0.9	L10	4.8	2.3
L0	18.2	1.5	L11	2.8	1
L1	10.9	0.1	L12	2.8	0.7
L2	1.1	0.5	L13	1.6	2.4
L3	0.4	6.9	J6	10.1	1.1
L4	15.7	17.2	K6	4.5	3.8
L5	0.6	1.4	M6	1.7	3.5
L6	3.5	0.8	N6	5.5	2.8
L7	25.5	1.1	O6	3.1	2.7
L8	3.6	1.7	P6	6.6	0.6
L9	0.6	0.1	Q6	1.5	2.8
		Geometric mean		3.34	1.58

The relationship between v_a and $T_{a\ measured}$ was also determined in 1991/92 and 2002/03. The result is given in Figure 3.

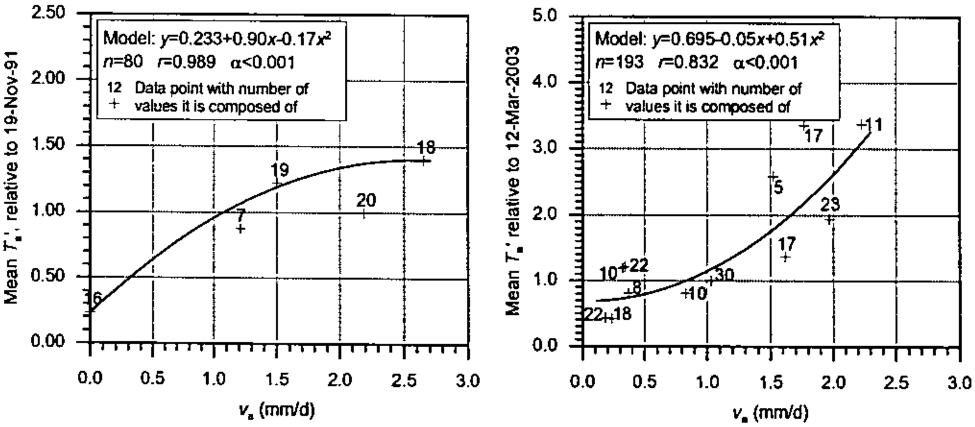

Figure 3. Relationship of v_a and T_a' of a number of sites, where T_a' is acrotelm transmissivity expressed relative to T_a on a reference date.

According to the assumptions underlying Eq. 5, the relationship of v_a and T_a should be approximately linear. In 1991/92 a linear relationship only held for v_a below 1.5 mm d^{-1}. At discharges >1.5 mm d^{-1}, hollows and pools interconnected, thus creating a flow *via* open water instead of the acrotelm (Van der Schaaf, 1999). In 2002/03 the linear part of the fitted curve was found to exist at specific discharge values over 0.8 mm d^{-1}. The part of the curve for larger discharges lies therefore closer to the theoretical relationship of v_a and T_a. This also suggests a recovery of the acrotelm since 1991, which is in agreement with the results shown in Table 1. At low discharges, water flows through the lower part of the acrotelm. The acrotelm in this part grew when growth conditions varied largely due to damage of several kinds. During the last decade, some flow barriers of more decayed material of the time damage was inflicted may have subsisted in the acrotelm, thus causing relatively low flow rates in newly developed acrotelm. This may have created an acrotelm with a more variable transmissivity than would have occurred under entirely natural conditions. This may explain why points in the graph between 0 and 0.5 mm d^{-1} with almost the same specific discharge vary so strongly in transmissivity and why the fitted curve becomes relatively flat at v_a between 0 and 1 mm d^{-1}.

3. Acrotelm depth

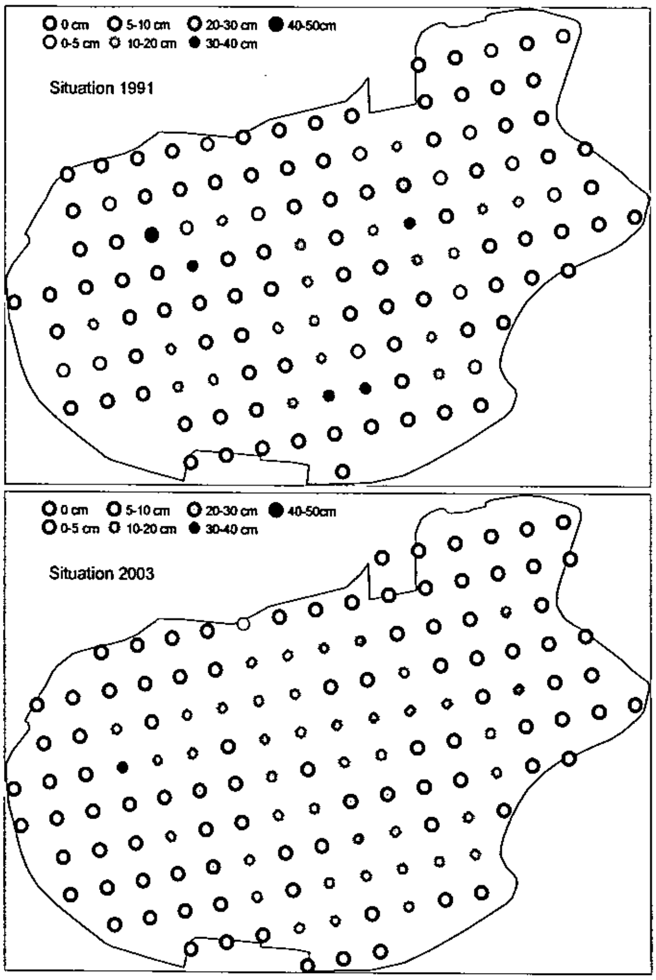

Figure 4. Acrotelm depths in 1991/92 (above) and 2002/03 (below).

At all nodes of the grid shown as dots in Fig. 2, the acrotelm depth was measured. It was defined as the depth to where the degree of humification was 3 or less on the Von Post scale (Von Post, 1922). The results are shown in

Figure 4. In 1991 a well-developed acrotelm only occurred in the central part of the bog, whereas in 2003 it stretches more towards the margins as well.

4. Conclusions

The comparison of the situations on Raheenmore Bog in 1991 and 2003 shows an improvement in actual acrotelm transmissivity, hence a greater role of the acrotelm in the discharge of water at large discharges and an overall increase in acrotelm depth. If in an undisturbed bog the actual T_a is approximately equal to the potential T_a (Van der Schaaf, 2002), Raheenmore Bog has not yet reached its optimum. The results obtained during the fieldwork of 2002/03 are rather hard evidence that Raheenmore Bog is recovering from past damage. At the same time the results suggest that the theory of potential acrotelm transmissivity based on flow path, flow pattern and surface slope is likely to be correct and applicable to Atlantic raised bogs.

Acknowledgement

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