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Controls on peat hydraulic conductivity: bridging the gap between models and measurements

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Peat hydraulic properties such as saturated hydraulic conductivity (K_{sat}) are variable in space and time. A broadly accepted but poorly understood relationship between peat decomposition and K_{sat} is highly influential on the behaviour of models of peatland development, but existing data do not allow this relationship to be parameterised satisfactorily. Previous empirical studies have typically used simple metrics of time-integrated decomposition such as fibre content, von Post score or light transmission (humification) to predict K_{sat}. By contrast, peatland development models represent the state of peat decomposition as a more abstract fraction of remaining mass. As such, a gap exists between the requirements of simulation models and the available empirical data – a gap that we seek to address.

We collected fourteen shallow ($\sim$ 0.5 m long, 0.1 m diameter) peat cores from a Swedish raised bog. Our sampling locations comprised two vegetation microhabitats, hummocks and hollows (n = 7 for each), combined factorially with two locations – the flat, treeless, central bog plateau (n = 8) and the treed, sloping bog margin (n = 6). In the laboratory we split the cores into 0.06 m depth intervals and measured horizontal K_{sat} and dry bulk peat carbon to nitrogen concentration ratios (C:N). Following a published method we used these C:N values to approximate the state of peat decomposition (fractional mass remaining) for depth intervals deeper than $\sim$ 0.1 m.

We used a step-up procedure to fit a linear mixed-effects (LME) model to the data, so as to predict $\log_{10}$ (K_{sat}) from two continuous predictor variables, depth and our C:N-derived approximation of fractional mass remaining; and two categorical predictors, microhabitat (hummock, hollow) and location (central plateau, bog margin). The LME model predicts that $\log_{10}$ (K_{sat}) declines linearly with increasing depth below the surface (p < 0.001) and with increasing peat decomposition (p = 0.012); and that it is greater in hummock peat than in hollow peat (p < 0.001). The categorical distinction between central and marginal areas exerted no significant effect (p = 0.880).

Our LME model illustrates for the first time the nature of the relationship between K_{sat} and fractional peat mass remaining, and suggests that changes are required to the form of the algorithms used to predict K_{sat} in peatland development models. Specifically, depth is usually ignored as a predictor variable, but in our study depth exerts a strong control over K_{sat} independently of decomposition. Our findings also add weight to the growing argument that the assumption of lower K_{sat} in hummocks than in hollows – commonly adopted in modelling studies – should be revised.