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Model analysis of carbon fluxes in a developing fen / bog complex

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Introduction

During the period since the last glaciation 300-455 Pg carbon have accumulated in Northern peatlands. Consequently, these peatlands have acted as large net sinks of atmospheric carbon. However, there has been only limited development in the analytical modelling of this peat growth. This paper describes the development and analysis of a model of carbon cycling for a developing fen / raised peatland complex. The model presents peat growth as a stack of parcels of organic matter within the peat body. Each parcel of organic matter has a labile component and a non-labile component with associated carbon fractions. Peat accumulation is described by the annual addition of new parcels of organic matter at the top of the stack. Consequently, as time passes each parcel is buried beneath the organic matter of the next parcel generated through the primary productivity of the surface vegetation.

Model description

The model distinguishes between the accumulation of organic matter and carbon in a generalised fen and that within a *Sphagnum* dominated raised bog.

The development of the fen and its hydroseral succession may be described through the periodic deposition and accumulation of organic matter at the bottom of a lake. Thus with the passing of each period a new parcel of organic matter is added to the lake floor and matter accumulates. Decay within the accumulating deposits is anaerobic. Aerobic decay in the waters above the accumulating deposits diminish the inputs from net primary productivity. Potentially such a process may be constructed so as to generate a convergent sequence tending to some limit as time tends to infinity. Where equal masses of organic matter are deposited per unit time the process may be represented as a type of geometric progression. The sum of the terms of such an infinite geometric progression represents an infinite geometric series of the form:

$(a+x) + (ar+x) + (ar^2+x) + \ldots (ar^{n-1}+x) + \ldots$

Such that the sum S_n of the first n terms is given by $S_n = \dfrac{a(1-r^n)}{(1-r)} + nx$

Where a is the labile organic matter and x is the non-labile organic matter.

The model uses such a discrete process description to simulate and evaluate the changes in the fen lake depth with time which in turn define the hydroseral progression. Consequently, as the lake becomes shallower the net primary productivity of the surface vegetation and aerobic decay are modified to simulate the vegetational succession. The establishment of *Sphagnum*, and with it raised peat development, is deemed to arise when the lake has been filled by accumulating organic matter.

A different set of parameter values apply to the development of the raised bog. The initial establishment of raised peat is represented by a layer of aerobically decomposing sphagnum peat, the acrotelm. This zone is characterised by the weighted average bulk density of the incoming parcels of organic matter generated through primary productivity. The average bulk density of these parcels is less than a specified value called the critical bulk density which defines the boundary between the acrotelm and the catotelm. However, as the mass and carbon content within the labile fraction of each parcel of organic matter input is removed by decay, the volume of labile material decreases and the weighted average bulk density increases. Consequently, as raised peat development proceeds the critical bulk density is reached and the parcel is then considered to have developed to the point where it enters the anaerobic catotelm. In this way the model generates the acrotelm-catotelm boundary. The specific decrease in labile volume, and hence total parcel volume determines the depth contribution of each parcel to the depth of the core. Raised peat depth is the sum of the volume of the individual parcels as their area is deemed to remain constant.

The model output provides profiles of total peat mass, carbon sequestration and depth with time for both the fen peat and raised peat strata. The output also generates profiles of bulk density with depth for the whole peat core. These outputs are compared and evaluated against available data for Irish peatlands at Clara and Mongan, Co. Offaly.

Conclusion

In the case of peat development this model suggests that profiles of depth and carbon mass with time should be represented by curves which are steeper initially and slowly approach a linear steady state of increase with an ever reducing rate of change with time. This model generates outputs that display this process. The linear condition depends on the non-labile fraction of the organic matter input. This is distinct from other approaches which have assumed that decay applies to all organic material in the bog. However, within the time frames concerned, it seems reasonable to treat the non-labile fraction as having a decay rate that is so close to zero as to be negligible. The resulting profiles generated by the model are consistent with data gathered from Irish midland raised bogs.