What is DigiBog and what data does it need?

Authors: Andy Baird, Paul Morris, and Dylan Young.
Date: 7th May 2020

Summary of data needed for the CongoPeat DigiBog modelling work

Setting up and running DigiBog

- A digital elevation model of the ‘pre-peatland’ land surface (**Work Package 1b**).
- When, in past time, to start a simulation – provided by calibrated basal ^{14}C dates from the peatlands being simulated (**WP1a**).
- Net rainfall (rainfall minus evapotranspiration) and air temperature for the period represented by a model run.
- Rates of above-ground litter production for each main plant functional type (PFT) (available from the GEM plots work – **WP2c**).
- Rates of below-ground litter production (root production) for the PFTs (available from the root ingrowth core and minirhizotron work – **WP2c**).
- Litter and peat decay. Data on decay and its controls will be obtained from the process measurements; i.e., the lab. experiments and the field observations (**WP2b/2c**).
- Peat hydraulic conductivity (*K*) for the different types of peatland/peat found in the Congo. This information is being provided through the piezometer and MiniDisk tension infiltrometer measurements (**WP2b/2c**).

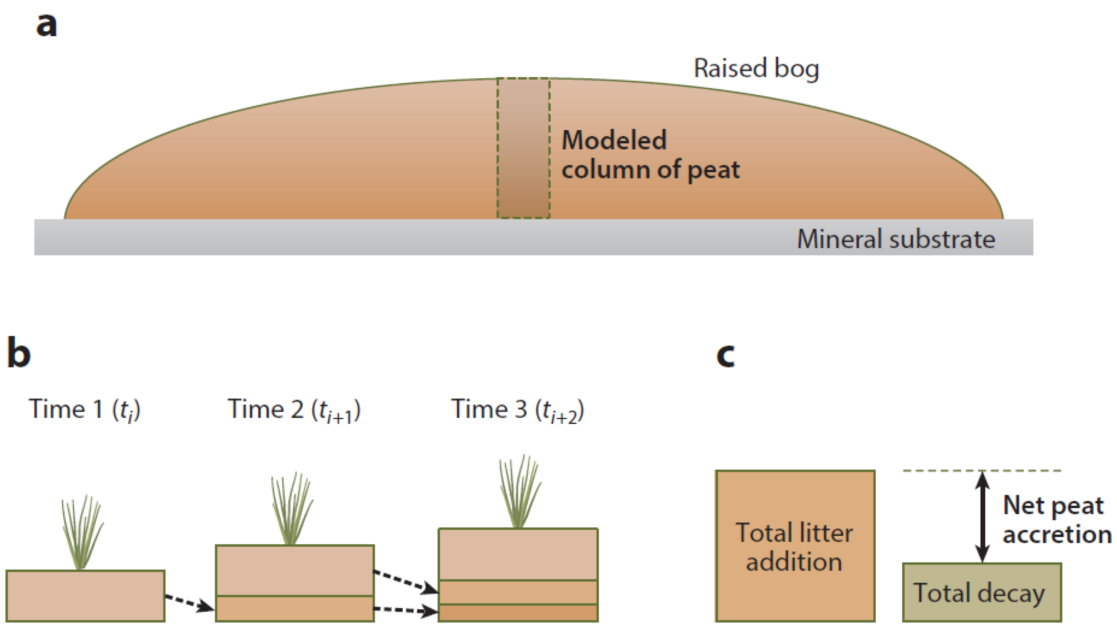
Testing model predictions

- Peatland depth and height from the transect (peat depth probing and coring) work and the LiDAR surveys and other EO datasets (**WP1a/1b**).
- Down-core palaeo data (**WP1a**): (1) degree of decomposition; various proxies including von Post score, humification, and biomarkers; (2) plant macrofossil remains; (3) water-table reconstructions using testate amoebae remains (other water-table reconstruction methods may also be available); and (4) age-depth curves.

More detail on these requirements is provided below.

What does the model do?

DigiBog simulates the development of a peatland over millennial timescales; in essence, it grows a virtual peatland. Simulations begin from one of several types of pre-existing surface (e.g. bare mineral ground, infilled lake) to which new plant litter is added on an annual basis (i.e. the peatland grows up from the pre-existing surface). Litter/peat within the developing peatland decays. The peatland will increase in mass and height if the annual addition of new litter exceeds the annual decay of existing litter and peat. The basics of what the model does can be summarised using the figure below taken from Page and Baird (2016).



The basic structure of DigiBog (from Page and Baird, 2016). Typically, DigiBog simulates the development of a peatland using multiple, contiguous columns of peat. For simplicity, the figure shows how one column of peat (a) builds up over time. Cohorts of new litter/peat are added during each annual time step of the model (b). At time step 1, the peatland consists of a single cohort of litter/peat. At time 2, a fresh cohort is added on top of the first cohort, which has undergone some decomposition and a decrease in thickness. At time 3, a further cohort is added, while the first and second cohorts undergo further decomposition. The total litter added, as well as the amount of litter that has been lost to decay are shown in (c). The difference between the two, as shown by the double arrow, represents the increase in overall thickness of the peatland. Although not shown here, belowground litter production (root production) occurs in many peatlands and can be represented in future versions of the model.

DigiBog also contains a hydrological submodel that simulates the dynamics of the water table across a peatland as a function of rainfall additions, evapotranspiration losses and subsurface flows through the peat to the peatland's margin. The position of the water table in any part of the peatland affects rates of litter production and also rates of decay, with decay highest in the zone above the water table.

The model can simulate peatland degradation (net peat loss) as well as peatland growth (peat accumulation). For example, during a period of multi-decadal drought, peatland water tables will fall (deepen) and decay increase. If decay then exceeds litter production, the peatland will lose mass and the peatland will subside. Management effects, due, for example, to the excavation of drainage ditches for oil palms, can also be simulated in the model. For northern peatlands, ditches in the model have been shown to cause substantial losses of peat mass and carbon (Young *et al*., 2017).

What data does DigiBog need?

Driving the model

To set up a model simulation, we need a digital elevation model of the 'pre-peatland' land surface (**WP1b**). We also need to know when, in past time, to start a simulation. This information can be provided by calibrated basal ^{14}C dates from the peatland being simulated (**WP1a**). Finally, the model requires inputs of net rainfall (rainfall minus evapotranspiration) and air temperature, usually as monthly totals/averages for the entire period represented by a model run (millennia in typical cases). We will use palaeoclimate simulations from an Earth system model to drive DigiBog throughout the Holocene. Paul will provide the necessary Holocene climate data, chosen from one of several Earth system models including HadCM3 and TraCE-21ka.

Process representation within the model

Currently, the model is set up to simulate northern temperate peatlands and will need modifying for the tropical, and specifically the Congo, case.

• Litter production

Litter production in the model is currently represented by up to four plant functional types (PFTs). The rate at which these produce litter depends on the depth to the water table and on peat temperature which is assumed in the model to be the same as air temperature. To set up the model for a Congo simulation we need to know:
(i) Rates of above-ground litter production for each main PFT. We assume that at least two PFTs will be needed – hardwood and palm – but will be guided by the field teams on what to include. We would also like to know how litter production varies with water-table position and temperature. Information on above-ground litter production is available from the GEM plots work (**WP2c**).
(ii) Rates of below-ground litter production (root production) for different PFTs. This information is available from the root ingrowth core work and the Masters work being done by Matteo with the minirhizotrons (**WP2c**).

• Litter and peat decay

Litter and peat decay in the model are described by exponential functions (proportionate decay rate models). Rates of decay can be modified by litter type, temperature, and redox. In the model, litter type is currently related to PFT but the model will be adapted to include different parts of the plant: e.g., leaves, above-ground woody material, roots. Regarding redox, it is currently assumed in the model that conditions above the water table are oxic, while below the water table they are anoxic; the model could, however, be modified to account for oxygen loss from roots below the water table. The model can also represent the increasing recalcitrance of litter/peat as it becomes more decomposed. We anticipate obtaining data on the controls on decay rates from those doing the process measurements; i.e., the lab. experiments (e.g. on the effect of temperature on decay rates) and the field observations (e.g. litter-bag study, soil+root respiration measurements, CH_4 flux measurements) (**WP2b/2c**).

• Water flow: peat permeability

In its water table submodel, DigiBog simulates water flow through the peat. The subsurface rate of flow depends in part on the peat's permeability or (more correctly) hydraulic conductivity (*K*). The model currently simulates *K* as a function of degree of decay: the more decayed a cohort of peat is, the lower its *K*. There is good evidence that the *K* of tropical peat is very different from that found in northern peatlands, but there is also good reason to believe that the Congo peats are somewhat different from those found elsewhere in the tropics. Therefore, we need measurements of *K* from the different types of peatland found in the Congo, and also of how *K* varies with degree of peat decomposition. This information is being provided through the piezometer and MiniDisk tension infiltrometer measurements (**WP2b/2c**). We already have a good dataset from the latter that can be used to update the model and that is of sufficient size and detail to form a paper (to be led by Nick and Greta). It would, however, be useful to obtain more down-profile data using piezometers.

Testing DigiBog's predictions

The virtual peatland simulated by DigiBog can be 'cored', and virtual cores compared with real cores as a test of the model's accuracy. The model's overall prediction of peat thickness is perhaps the most basic test of its accuracy: does it simulate the right amount of peat and does it simulate the right shape of peatland? Information on peatland depth and height is being provided by the transect (peat depth probing and coring) work and by the LiDAR surveys and other EO datasets (**WP1a/1b**).

Within each virtual core, DigiBog contains downcore information on:
(i) degree of decomposition of the peat;
(ii) the make up of the peat in terms of plant PFT and parts of the plant (leaves, woody material, roots);
(iii) water-table depths below the peatland surface when the peat in any part of a core was first formed.

These model outputs 'map onto' measurements being made by the palaeo team (**WP1a**). Degree of decomposition in the model is expressed as proportion of original mass remaining. This is the amount of organic matter that remains from an original mass of new litter, expressed as a fraction (i.e., mass left / original mass). To our knowledge, there is no measurement that replicates this output directly. However, various proxies could be used, including von Post score, humification (e.g., Chambers *et al*., 2011), and biomarkers (e.g., Dehmer, 1993 and Routh *et al*., 2014).

The virtual plant remains map directly onto plant macrofossil remains found in the real cores, while the virtual information on water-table depths can be compared with water-table reconstructions using testate amoebae remains from the real cores (other water-table reconstruction methods may also be available as discussed by Arnoud in a previous CongoPeat meeting; e.g., via analysis of the deuterium composition of leaf waxes). Finally, the virtual core also has its own age-depth curve that can be compared with the age-depth curve from the real cores; therefore, variations in apparent rates of carbon accumulation (ARCA) over time can be compared between virtual and real cores.

References

Chambers, F.M., Beilman, D.W. & Yu, Z. 2011. Methods for determining peat humification and for quantifying peat bulk density, organic matter and carbon content for palaeostudies of climate and peatland carbon dynamics. *Mires and Peat*, 7, Article. 7.

Dehmer, J. 1993. Petrology and organic geochemistry of peat samples from a raised bog in Kalimantan (Borneo). *Organic Geochemistry*, 20, 349–362.

Page, S.E., and Baird, A.J. 2016 Peatlands and global change: response and resilience. *Annual Review of Environment and Resources*, 41, 35–57.

Routh, J., Hugelius, G., Kuhry, P., Filley, T., Tillman, P.K., Becher, M., and Crill, P. 2014. Multi-proxy study of soil organic matter dynamics in permafrost peat deposits reveal vulnerability to climate change in the European Russian Arctic. *Chemical Geology*, 368, 104–117.

Young, D.M., Baird, A.J., Morris, P.J., and Holden, J. 2017. Simulating the long-term impacts of drainage and restoration on the ecohydrology of peatlands. *Water Resources Research*, 53, 6510–6522.