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Modelling peatland dynamics: Many models, same questions

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Globally, peatlands are important carbon and freshwater storage areas that have been extensively degraded by anthropogenic and natural disturbances. Considering the interconnected processes and high degree of heterogeneity in peatlands, simplified modelling approaches for peatland dynamics are prone to uncertainty, which has contributed to a proliferation of conceptualizations and parameterizations. While it is essential to improve modelling frameworks, creating new models with the same approaches and structures can make it difficult to identify uniqueness within the plethora of models, resulting in duplication of effort and resource waste. Here, we present a systematic review based on peer-reviewed journal publications to identify the most commonly used process-based models for simulating peatland dynamics. We selected 44 models that appeared at least twice and reviewed their corresponding publications (n = 211) to determine principal use-cases, types, and locations of peatlands. As a result, the models were grouped into four main types: terrestrial ecosystem models (biogeochemical and global dynamic vegetation models, n = 21), hydrological models (n = 13), land surface models (n = 7), and eco-hydrological models (n = 3). Out of all the models, 11 were peatland-specific, while the rest were generic. The scale of the studies ranged spatially from the catchment area to global and temporally from months to decades. In total, 19 studies were conducted at the global scale, 6 in the northern hemisphere, 5 in lab-based or synthetic setups, and 181 involved regional scale catchments; Among the latter, the majority were northern (temperate to arctic) peatlands. When the types of peatlands were mentioned, bogs were the most common (n = 52), followed by fens (n = 41), permafrost (n = 31, 20 of which were combined with bogs, fens, or peat swamps), mixed fen-bogs (n = 27), and blanket peats (n = 11), most of which were drained. Only three models were explicitly used to simulate tropical peatlands, and no models were found for Patagonia (Latin America). The simulations primarily focused on hydrology (39%), followed by carbon dynamics over large spatial scales (33%), energy fluxes and soil temperature (12%), peat accumulation (7%), and nitrogen fluxes (3%). Following a FAIR (Findable, Accessible, Interoperable, Reusable) assessment, the number of models was reduced to 12. Then, we compared the spatio-temporal resolution flexibility, input data file format, and modular structure of the shortlisted models. We found that several models of the same type have been developed/modified for the same application, climate zone, and with similar approaches. This points to opportunities for reducing duplication of effort and reusing models, while also suggesting that models developed for a similar use-case required similar parameterization. In this respect, our review highlights the need for a 'peatland community modelling' strategy that allows researchers to collaborate more efficiently and consolidate

knowledge gleaned from various models.