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Estimation of soil organic carbon and nitrogen stocks in Irish peatlands using a predictive modeling approach

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Peatlands play a crucial role in the global carbon cycle and are a major ecosystem with potential to remove greenhouse gases from the atmosphere. Ombrotrophic peatlands constitute the largest soil organic carbon (SOC) stock in Republic of Ireland (ROI) and cover an estimated 20% of the land surface. Peatland nitrogen (N) stock remains unknown, despite its crucial role in peatland degradation with subsequent nitrous oxide (N_2O) emissions and eutrophication of downstream ecosystems. Land use impacts are major drivers of both peatland carbon and N stock degradation and disturbance of the peatland carbon sink function. Hence, in the context of this research it is assumed that past and present land use activity, including afforestation, grazing, and domestic and industrial peat extraction for energy and horticultural use, are likely to affect peat SOC and N stocks.

To date, estimation of the peat SOC-stock in ROI was based on non-directly measured values of SOC-concentration, dry bulk density and peat depth. In this study, these properties were measured for the first time along the entire peat soil profile at national scale across the major ombrotrophic peatland types and land uses. A predictive modeling approach, which compared linear and additive mixed-effects models, formed the basis for quantifying SOC and N stocks. The approach encompassed a model evaluation that used an iterative data-splitting algorithm, combined with an assessment of the bias-variance trade-off.

Our results depict a similar pattern for both SOC and N stocks, with mean stock estimates (t ha^{-1}) largest for near-natural bogs. The largest total amount (Mt) of SOC and N was stored in bogs (recently) used for domestic peat extraction. Stock calculations based on modelled SOC and N values resulted in initial estimates for the entire national peatland area and peatland type-land use strata of Irish peatlands. They revealed that national peatland SOC is nearly twice as large as previously calculated. Mixed-model analysis of main stock determinants revealed major influence of peat depth for quantification of stocks. It confirmed that land use exerts a strong influence on bulk density and SOC, whereas peat depth was found to be strongly associated with land use category.

The presented approach allowed quantification of SOC and N stocks for larger areas based on clustered soil data. It provided a methodology for identifying the best performing model to be

implemented in stock assessments, thereby avoiding under- or over-parameterization. The study fills a gap in peat SOC quantification in ROI by updating existing uncertain estimates for peat SOC stock, and by providing the first estimates for national ombrotrophic peat N stock, based on measured covariates.