A Synthesis of *Sphagnum* Litterbag Experiments: The Role of Initial Leaching Losses and a Test of the Holocene Peatland Model

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Introduction

Litterbag experiments (LE) allow us to learn about the controls of *Sphagnum* decomposition and they provide decomposition rate (k_0) estimates to make long-term predictions of peat accumulation with peatland models such as the Holocene Peatland Model (HPM) (Frolking et al. 2010).

We test (1) whether the HPM can reproduce k_0 estimated from LE under oxic and anoxic conditions. Moreover, (2) initial leaching losses (l_0) in LE may bias k_0 estimates and (3) LE and HPM parameters have inherent uncertainties. Potentially, these two factors could strongly affect whether LE data can be reproduced by the model and in turn whether models such as HPM can reasonably predict peat accumulation.

We addressed (2) with simulations and by estimating l_0 from available data with a decomposition model compatible with the HPM and (3) by combining the LE decomposition model and the HPM decomposition module in a Bayesian model. We then tested whether the HPM can predict k_0 estimated from LE to address (1).

Intial leaching losses

Are initial leaching losses (l_0) large enough to bias k_0 estimates?

Our simulation indicates that k_0 will be overestimated proportionally to the true l_0 and that uncertainties increase if initial leaching is ignored (Fig. 1 (a)). Values of l_0 estimated from available LE obtained through a systematic literature review would be large enough to cause such bias (Fig. 2). As a consequence, long-term predictions could underestimate peat accumulation by several tens of mass-% (Fig. 1 (b)).

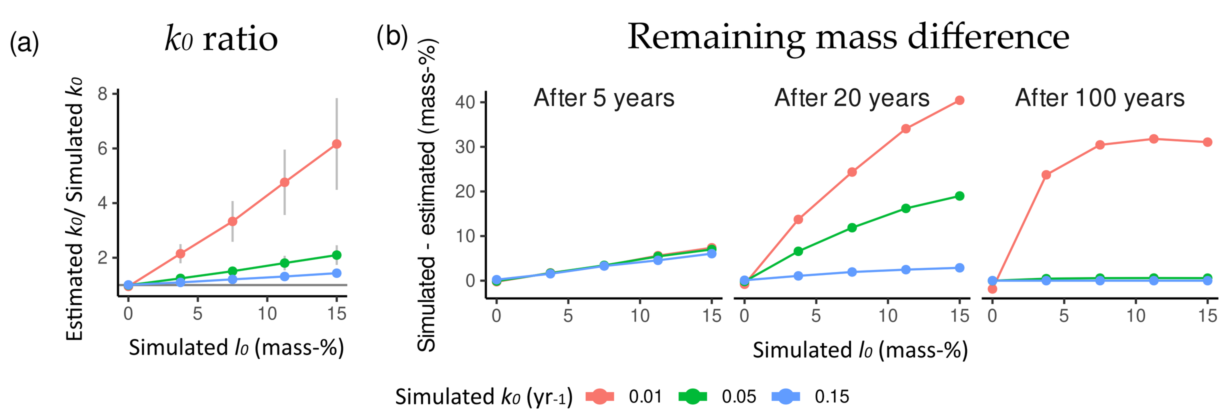

Figure 1: LE data with different k_0 and l_0 were simulated and then a one-pool exponential decomposition model ignoring initial leaching was fitted to the data. Shown are comparisons of the estimated and true parameter values.

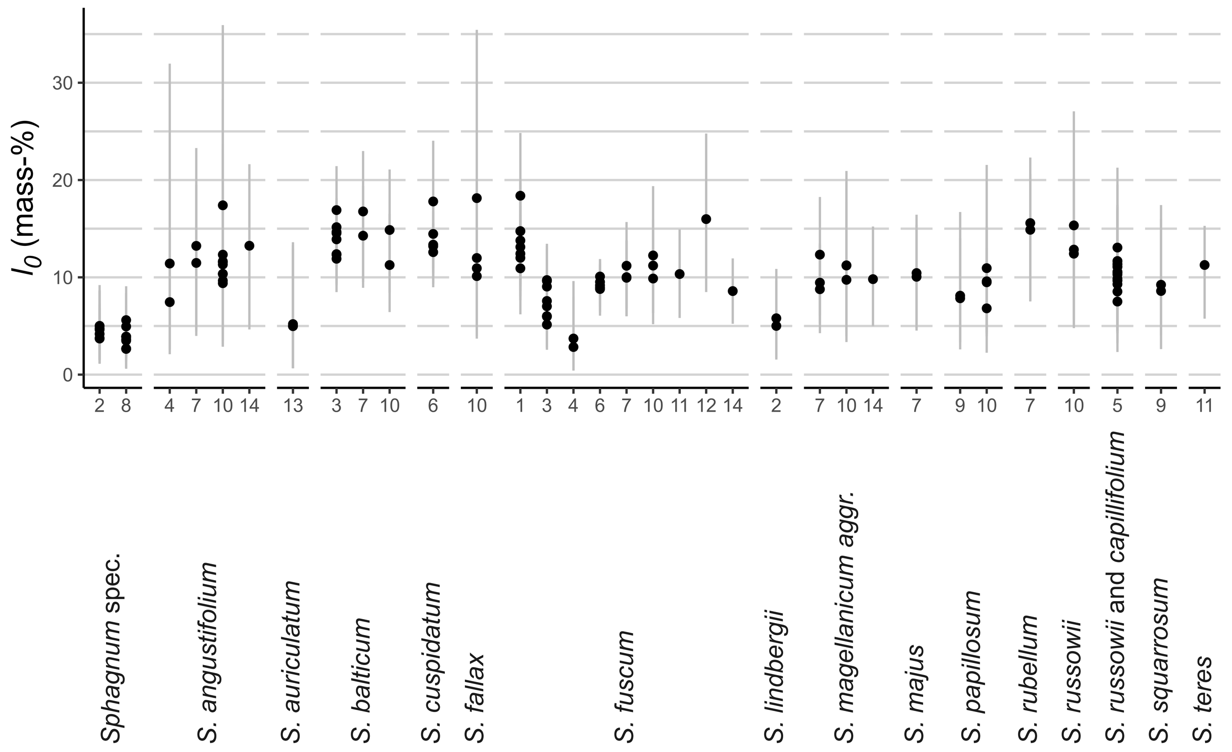

Figure 2: l_0 estimated for 129 *Sphagnum* LE from 14 different studies (average and 95% prediction interval). Average l_0 range between 3 to 18 mass-%. Numbers indicate studies.

HPM Test

Can the HPM fit LE data?

To test the HPM decomposition module, we computed four model versions (Tab. 1) and compared k_0 estimated from LE versus k_0 predicted by the HPM.

Table 1: Models computed to test the HPM and estimate its parameters from LE data.

Model	Description
3-1	Standard HPM, LE decomposition model separated.
3-2	Standard HPM combined with LE decomposition model.
3-3	HPM combined with LE decomposition model, HPM parameters estimated.
3-4	Same as model 3-3, plus models how l_0 depends on the degree of saturation.

Uncertainties in LE k_0 and l_0 allow to adjust LE k_0 and l_0 estimates such that they fit HPM predictions (Fig. 3, model 3-2). But the price is to assume larger l_0 and smaller k_0. How realistic this is needs to be tested.

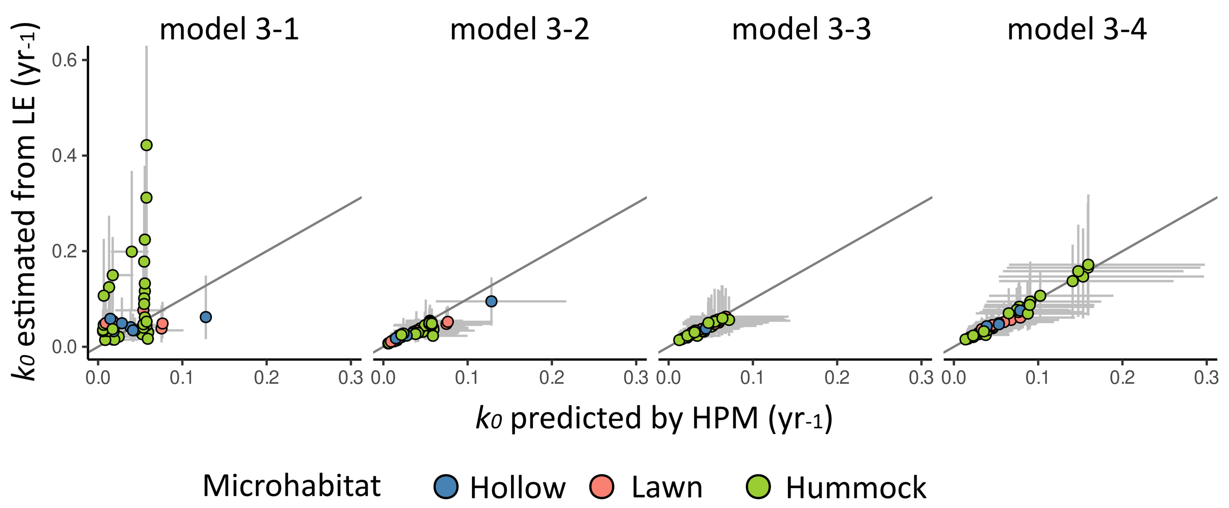

Figure 3: k_0 estimated from LE versus k_0 predicted by the HPM modifications.

A better fit of the HPM can be achieved if W_{opt} and c_2 are increased relative to their standard values (Fig. 3 and 4, Tab. 2).

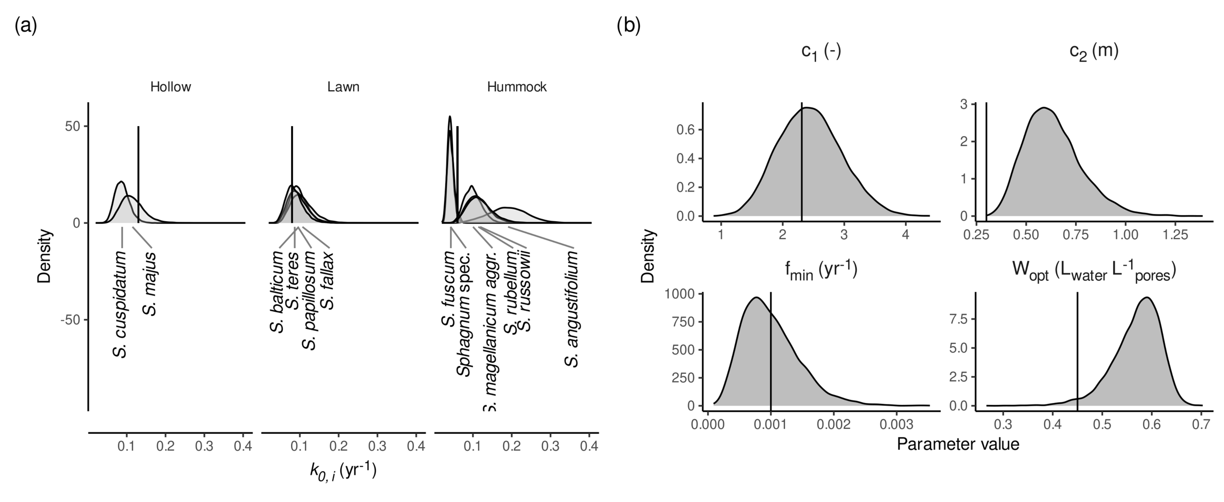

Figure 4: HPM parameters estimated from LE data by model 3-4. Vertical lines indicate the standard parameter values used in Frolking et al. (2010).

Table 2: Parameters of the HPM decomposition module (Frolking et al. 2010).

Parameter	Description
W_{opt}	Optimum degree of saturation for aerobic decomposition.
c_1	Curvature of the relation of aerobic decomposition rates to the degree of saturation (larger values imply a more peaked relation).
f_{min}	Minimum anaerobic decomposition rate.
c_2	Anoxic scale length. Represents limitation of anaerobic decomposition rates with increasing distance below the annual water table depth.
$k_{0,i}$	Maximum possible decomposition rate for *Sphagnum* from microhabitat i = {hollow, lawn, hummock} (models 3-1 and 3-2) or for species i (models 3-3 and 3-4).

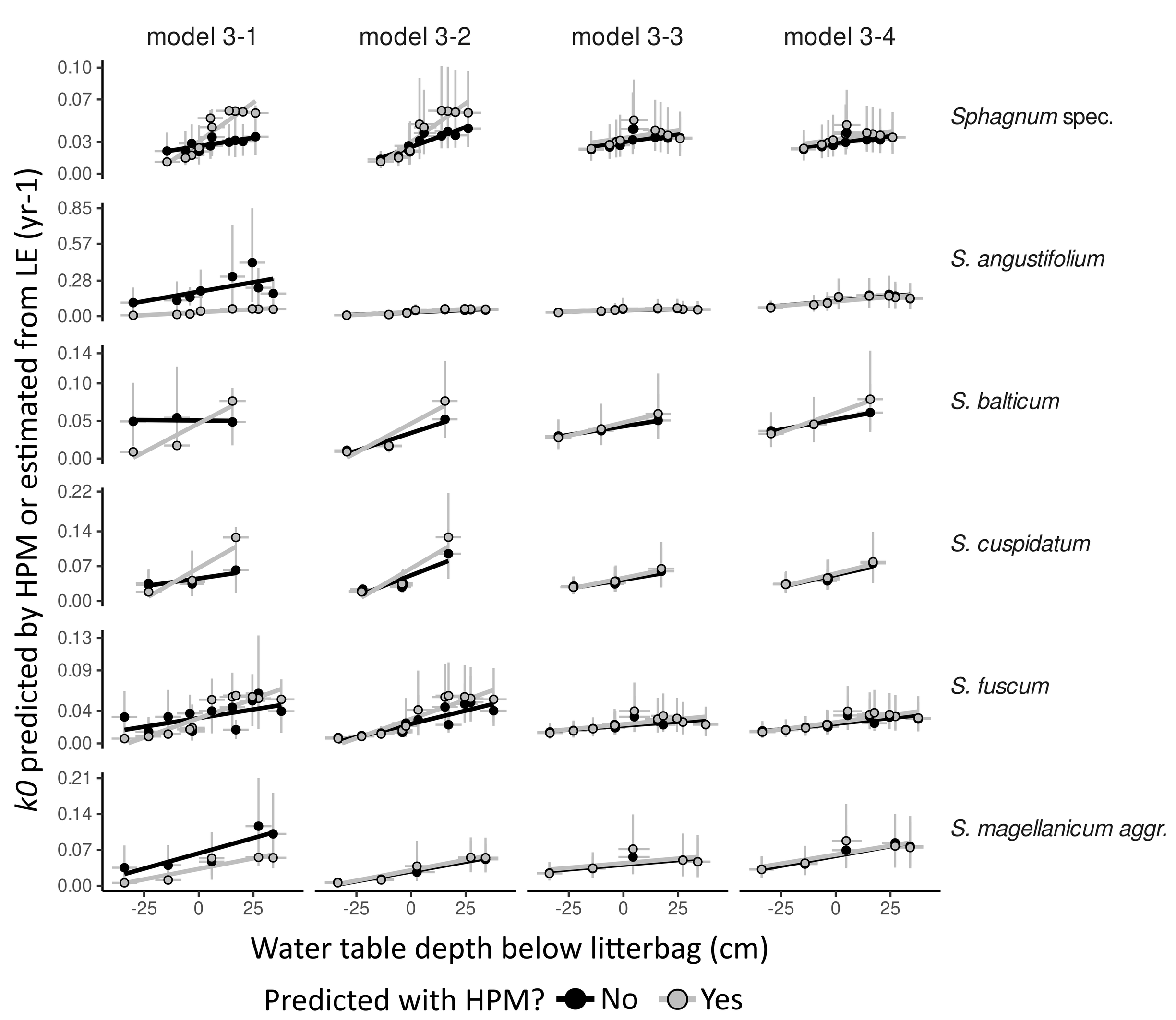

Figure 5: k_0 estimated from LE and predicted by the HPM modifications versus water table depth below the litterbag.

Anaerobic decomposition rates may be underestimated because of ignored water table fluctuations

Together, these changes in parameter values imply larger anaerobic decomposition rates and a less steep gradient from aerobic to anaerobic decomposition rates (Fig. 5). One possible explanation for this discrepancy is that the HPM ignores effects of seasonal water table fluctuations which would recycle electron acceptors and reduce accumulation of decomposition end products.

Conclusions

- Ignoring initial leaching losses biases k_0 estimates in LE decomposition models proportionally to the true initial leaching loss. Average l_0 estimated from available LE (3 to 18 mass-%) are large enough to cause non-negligible bias of long-term C accumulation estimates.
- The HPM with standard parameter values can fit *Sphagnum* LE data, but only if we assume even larger l_0 than estimated from LE data alone.
- Estimating HPM parameters from available LE data indicates larger anaerobic decomposition rates and a less steep gradient from oxic to anoxic conditions. This can imply over- or underestimation of 5000 year C accumulation by up to ca. 20%, depending on climate (Quillet et al. 2013).
- More accurate l_0 estimates are necessary for more accurate k_0 estimates and a better test of the HPM or other peatland models. This requires an improved design of LE.

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References for the Poster: A Synthesis of *Sphagnum* Litterbag Experiments: The Role of Initial Leaching Losses and a Test of the Holocene Peatland Model

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In Fig. 2 the study is indicated by numbers on the x axis: (1) Asada and Warner (2005), (2) Bartsch and Moore (1985), (3) Breeuwer et al. (2008), (4) Golovatskaya and Nikonova (2017), (5) Hagemann and Moroni (2015), (6) Johnson and Damman (1991), (7) Mäkilä et al. (2018), (8) Prevost et al. (1997), (9) Scheffer et al. (2001), (10) Straková et al. (2010), (11) Szumigalski and Bayley (1996), (12) Thormann et al. (2001), (13) Trinder et al. (2008), (14) Vitt (1990). *Sphagnum* spec. are samples which have been identified only to the genus level.

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