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The Assumptions of the Tea Bag Index and Their Implications: A Reply to Mori 2025

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ABSTRACT

Responding to Mori (2025), we discuss that the simplifications and implications of the Tea Bag Index are essential to its ease of use. However, they necessitate careful attention, especially regarding the appropriate incubation time. Aligning with Mori (2025), we call for a deeper understanding of the interpretation of k_TBI .

1 | Introduction

The breakdown of organic material is the result of several processes (e.g., leaching, fragmentation, bleaching, enzymatic hydrolysis) that comprise the process of *decomposition*. The relative importance of these processes can change over time and space, across litter types and material fractions within a given litter type, but they all result in loss of organic material from the original unit (e.g., a leaf). A relatively straightforward and common way to study decomposition of plant material is by determining mass loss curves (Wieder and Lang 1982). However, such mass loss curves are laborious and time-consuming to obtain and difficult to compare across ecosystems because unstandardised leaf litter is used.

The Tea Bag Index (TBI) was introduced to provide an easy-to-quantify and standardised proxy for the decomposition

process of plant material during early phases of decomposition (Keuskamp et al. 2013). The method consists of incubating a slow-decomposing rooibos and a fast-decomposing green tea as equivalents of mesh bags with local leaf litter. The tea bag types are incubated for 90 days at 8 cm soil depth. Subsequently, the *observed* mass losses of rooibos and green tea are evaluated using a decomposition *model* with three fractions (i.e., decomposable (labile) material, stabilised material, and recalcitrant material). The model is *parameterised* by using the mass loss observed in rooibos and green tea and the hydrolysable fractions of both tea types (Figure 1). Hence, the TBI provides two proxies of decomposition dynamics: initial decomposition rate (k_TBI ; Box S1) and stabilisation factor (S_TBI , Box S1). The k_TBI is used to characterise initial mass loss rates of the hydrolysable fraction of rooibos, whereas S_TBI is used to characterise the built up of recalcitrant rest material from the hydrolysable fraction.

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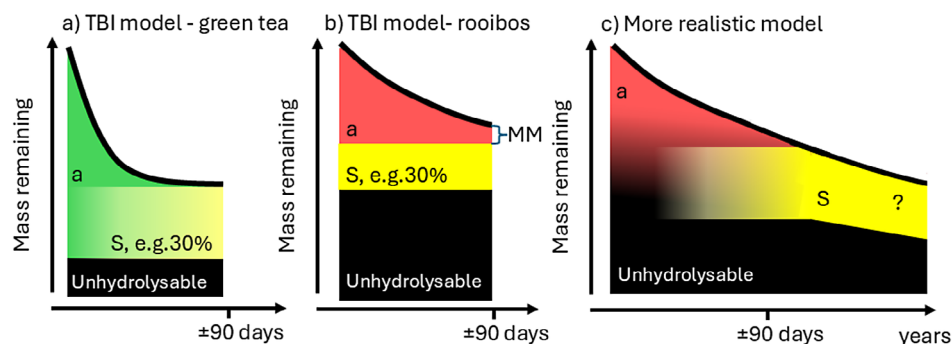


FIGURE 1 | Reasoning of the Tea Bag Index (TBI) model. (a) The TBI is underpinned by a three-fraction decomposition model, with (1) a labile fraction (*a*; green or red shading) which drives mass loss during early decomposition, (2) a stabilised fraction (yellow) which is derived from incomplete digested compounds from the hydrolysable fraction and (3) an unhydrolysable recalcitrant fraction (black) parameterised by Soxhlet analysis. Using the unique difference in decomposition dynamics between green tea and rooibos, the formation of the stabilised fraction is derived from green tea mass loss after 90 days. It is scaled to the hydrolysable fraction to obtain the stabilisation factor (S_{TBI}). In the TBI, the mass losses from the yellow and black fractions are assumed to be negligible on the short timescales of three months (Assumption 2). (b) To obtain fraction *a* for rooibos, *S* is scaled to the hydrolysable fraction of rooibos and mathematically assumed to form instantaneously (Assumption 3). The k_{TBI} is subsequently estimated from the observed mass loss of rooibos, provided that rooibos has not yet reached its asymptote (Assumption 1), which can be quantified by calculating a mass margin (MM). (c) TBI is a simplification of the reality, where the difference between the hydrolysable and unhydrolysable fraction is not as strict, unhydrolysable material decomposes from the start and can create rest products that are equivalent to hydrolysable material. Hence, TBI does not predict long-term decomposition dynamics (Sarneel et al. 2024).

In a recent analysis of the TBI, Sarneel et al. (2024) showed that, globally, k_{TBI} and S_{TBI} are negatively correlated, although certain environmental conditions (vegetation type and/or climate) can induce deviations from this general trend. In a response to the TBI method in general and to Sarneel et al. (2024) in particular, Mori (2025) pointed out that the correlations between k_{TBI} and S_{TBI} and deviations from the relation reported by Sarneel et al. (2024) should be interpreted cautiously because

Aspect 1: A mathematical dependence of k_{TBI} on S_{TBI} (derived from transferring S_{TBI} from green tea to rooibos) could bias correlation analysis.

Aspect 2: Fundamental differences in decomposition dynamics between both litter types resulting in different responses to environmental conditions could cause deviations from the general negative trend between k_{TBI} and S_{TBI} observed in Sarneel et al. (2024).

Aspect 3: A deviation between k_{TBI} and the observed initial decomposition rate, as derived from mass loss curves of rooibos of ca. 90 days (k_{real} ; Box S1).

With this work, we aim to contribute to the discussion on how and when the TBI should or should not be used by first examining its assumptions and subsequently by discussing the aspects raised by Mori (2025). To this end, we expanded the data set of 21 laboratory TBI timeseries incubations of tea used by Mori (2025) with nine unpublished time series (Table S1). With this expanded data set, we followed the procedure outlined by Mori (2025) and calculated k_{TBI} and $Asymptote_{TBI}$ predicted by the TBI at 90 days as well as the observed initial decomposition rate and asymptote (respectively, k_{real} and $Asymptote_{real}$; Box S1). We related the predicted and observed parameters to each other and investigated what determined the reliability of the prediction (for details on the methodological approach, see

Appendix S1). Since Mori's aspects tie to assumptions underlying the TBI, we first discuss these assumptions and conclude by responding to Mori (2025) explicitly.

Assumption 1. The acid unhydrolysable fraction does not decompose within 90 days.

Although parts of the lignified fraction can decompose in 90 days, initial decomposition rates are primarily driven by the loss of the labile, hydrolysable material fraction (Hall et al. 2020; Yi et al. 2023). Yet, the distinction between fractions may be less strict in practice, as partial digestion of the recalcitrant fraction can generate hydrolysable compounds (Aswin et al. 2024). Therefore, decomposition rates derived from timeseries data (TBI or otherwise) integrate mass loss rates of different fractions and processes. Consequently, higher decomposition rates can be observed in shorter time series (Figure 2a), as they primarily capture the rapid loss of labile material, whereas longer time series increasingly reflect the slower degradation of recalcitrant material. This means that timeseries observations of mass loss of rooibos tea may be incompatible with TBI (that aims to model the hydrolysable fraction) when Assumption 1 does not hold. The violation of Assumption 1 can be recognised by negative S_{TBI} values (suggesting unhydrolyzable fraction decomposition), which was observed in 2.37% of the analysed pixels in Sarneel et al. (2024), with a minimum of $S_{TBI} = -0.16$ (Figure S3). Although core to the TBI framework, it is often overlooked that longer periods are unsuitable for calculating the TBI decomposition parameters. To prevent too long incubations, Sarneel et al. (2024) restricted incubation duration (45–135 days).

Assumption 2. An incubation of 90 days allows green tea to reach stabilisation (S_{TBI}) and is sufficient for rooibos to reflect initial decomposition rate (k_{TBI}).

The slowly decomposing rooibos and the rapidly decaying green tea differ in their decomposition dynamics (Figure 1).

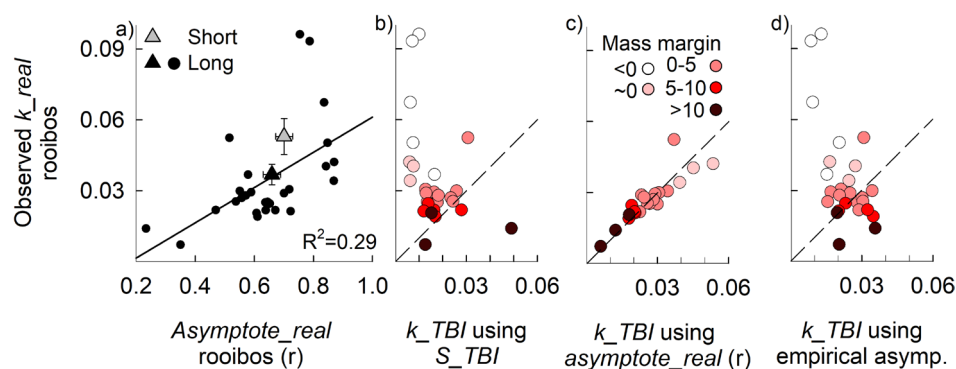


FIGURE 2 | The importance of the asymptote for k_{real} . The observed asymptote ($asymptote_{real}$) and observed initial decomposition rate (k_{real}) correlate positively in timeseries of rooibos tea (a). Triangles indicate means of the 24 successful fits and show that fits from shorter timeseries (60 days; triangle) result in a higher observed $asymptote_{real}$ and k_{real} compared to the longer timeseries (90–120 days). Error bars are SE. Despite the relationship between the mass loss in green and rooibos (suggesting transferability of stabilisation, Figure S2), S_{TBI} does poor in predicting the observed k_{real} in rooibos (b), especially when mass loss margins (indicated by dot colour) are small. The dashed line indicates the 1:1 line. Small mass margins suggest that rooibos has approached its asymptote at 90 days (Assumption 2; Figure S1), and those observations hence fall outside the TBI framework. Using the observed $asymptote_{real}$ of rooibos to calculate the k_{TBI} highly improves the predictive power (c), suggesting the sensitivity of k_{TBI} to estimation of the asymptote. However, using the empirical relation between the asymptotes of green tea and rooibos (Figure S2; Box S1) to predict the rooibos asymptote does not improve the predictive power of k_{TBI} (d).

After an incubation of ca. 90 days, the mass loss of rooibos represents the initial decay rates, whereas the mass loss of green tea represents an asymptote (Figure 1a,b). As Mori (2025) points out (Aspect 2) the mass loss of green tea and rooibos differ in their decomposition dynamics. Assumption 2 is needed to interpret this difference but, consequently, an incubation that is too long will result in rooibos reaching its asymptote, whereas green tea may not reach its asymptote when the incubation is too short. The latter will result in overestimation of k_{TBI} , and a positive correlation between k_{TBI} and S_{TBI} . Using the extended time series data, we quantified how close the TBI measurement was in relation to reaching the asymptote in both rooibos and green tea. To this end, we calculated the mass margin (Box S1) for both rooibos and green tea. To align Assumption 2, a TBI measurement would require a small mass margin for green tea and a large one for rooibos. We indeed observed a small mass margin for green tea (on average $0.2\% \pm 2.7\%$ SD of the initial dry tea mass; Figure S1a) but for rooibos, a larger variation in the mass margin was observed. Here, the differences between the predicted and observed initial decomposition rates decreased with increasing mass margins, suggesting a negligible differences at mass margins $> 5\%$ – 10% (Figures 2b and S1b). Calculating the mass margin for rooibos (Box S1) can quantify if this assumption is met. We suggest maintaining a mass margin of $> 10\%$ for rooibos. Though smaller margins may suffice (Figure 2), 10% provides a clear benchmark while remaining measurable in terms of mass loss precision.

In conclusion, the standard TBI incubation duration is suitable for green tea to reach its asymptote, yet it appears to be unsuitable to reliably calculate k_{TBI} on certain occasions (Figures S5 and S6). However, in the data set of Sarneel et al. (2024), we could not find clear environmental conditions that would more frequently result in violation of this assumption (i.e., mass margin rooibos $< 10\%$; Figure S7). We reproduced the results of Sarneel et al. (2024) by including only rooibos measurements that likely met Assumption 2 (with

mass margins $> 10\%$; including 66.4% of the tea bag incubations). This showed that, despite some changes in the absolute range of k_{TBI} , the overall patterns remained the same (Figures S5 and S6). However, given that the 90 days may be too long in one third of the considered measurements, a careful consideration of the incubation duration is needed (Box S1).

Assumption 3. The stabilisation factor scales with the hydrolysable fraction and can hence be transferred across litter types.

The literature on ‘limit factors’ suggests that stabilisation factors may scale with the chemical composition of the leaf material, since limit factors bear conceptual similarity to S_{TBI} . Nevertheless, Mori (2025) suggested that this is not the case (Aspect 3), since the asymptote predicted by the S_{TBI} does not correlate 1:1 with the observed $asymptote_{real}$ in the rooibos time series. However, the significant relationship between the observed $asymptote_{real}$ of green tea and rooibos ($F_{1,25} = 39.0$; $p < 0.001$; $R^2 = 0.59$) suggests that stabilisation factors of rooibos and green tea do scale. The divergence from the 1:1 line could be due to the TBI parameterisation, although using the parameterisation by Hayes et al. (2024; Figure S3) did not improve the predictions. Alternatively, it could be that the stabilisation of green tea may not scale identically with stabilisation in rooibos. When using the observed $asymptote_{real}$ of rooibos instead of S_{TBI} , a 1:1 correlation between the observed k_{real} and k_{TBI} was found (Figure 2c; Box S1). This suggests a high sensitivity of k_{TBI} to asymptote estimations. As an alternative way to predict the asymptote of rooibos (Mori, pers. commun.), we used the empirical relationship between the remaining mass fraction of green tea (the asymptote of green tea in TBI) and the $asymptote_{real}$ of rooibos ($F_{1,25} = 29.8$; $p < 0.001$; $R^2 = 0.54$; Figure S2). This, however, did not increase the predictive power of k_{TBI} (Figure 2d).

While this analysis supports the assumption that S_{TBI} is a parameter that can be transferred across litter types, it also shows

that (1) transferring S_TBI underpredicts the asymptote of rooibos and that (2) the determination of the initial decomposition rate is sensitive to the asymptote. Nonetheless, rooibos may reach its asymptote on timescales where the recalcitrant material will also start contributing more significantly to mass loss (see Assumption 1). This impairs the estimation of a stabilisation factor for rooibos and hampers comparisons of predicted and observed parameters. Further, S_TBI is mathematically implemented at the start of the decomposition, ignoring that at the incubation time when the TBI is calculated, stabilisation may not be completed yet. This would lead to faster k_TBI compared to k_real . In the time series, however, k_TBI underpredicts k_real (Figure 2a), making it unlikely that this is a major issue. Last, it should be stressed that transferring k_TBI across litter types is outside the scope of the TBI, as that would imply that all litter types would approach the asymptote at the same time.

2 | Response to Mori (2025), Conclusions and Perspectives

The TBI aims to provide an easily applicable method to gain insight into short-term decomposition dynamics of labile litter fractions and highlights that initial decomposition rates and asymptotes are separate characteristics of the decomposition process. The TBI, however, does not intend to elucidate the dynamics of labile versus recalcitrant litter types nor does it try to obtain site-specific insights in decomposition dynamics of local litter. The strength of the TBI lies in its simple application and its standardisation across time and space. This allowed Sarneel et al. (2024) to describe global patterns of k_TBI and S_TBI across environmental gradients. By analysing the relationships between each parameter and environmental conditions separately, Sarneel et al. showed an overall negative correlation as well as deviations from this relationship. Mori raised that a mathematical dependence (Aspect 1) as well as observations derived from different litters (Aspect 2) could contribute to these patterns. However, the observed relationship between *asymptote_real* and *observed k_real* (Figure 2a) corroborates that those parameters can be independently influenced by environmental conditions. In addition, as outlined by Mori et al. (2022), the mathematical dependence between k_TBI and S_TBI would induce a positive correlation, whereas Sarneel et al. (2024) observed that environmental conditions induced a negative correlation between k_TBI and S_TBI . Aligning with Mori's (2025) Aspect 3, we show that k_TBI often provides a poor estimation of k_real . We suggest that maintaining a mass margin (Assumption 2) could alleviate this issue, but our data set was too small to support this statistically. We further show that the mismatch between k_TBI and k_real derives from the high sensitivity of k_TBI (but likely k values in general) to the estimation of the asymptote.

In conclusion, the ecological interpretation of k_TBI calls for further investigation as it does not necessarily reflect the mass loss rates observed in rooibos tea. Whether it reflects the mass loss rate of hydrolysable material (as it intends to do) would require advanced chemical analysis. Yet, comparing litter types could benefit from considering which process drove the observed mass loss, especially since the initial decomposition rate and the asymptote are likely influenced by different environmental factors. As showcased in Sarneel et al. (2024) and here,

separating these parameters can provide valuable insights into decomposition.

Author Contributions

J.M.S. wrote the original draft with significant input from all other coauthors.

Acknowledgements

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Data Availability Statement

The data added to the data described in Mori (2025) is available on zenodo <https://zenodo.org/records/15083202>.

Peer Review

The peer review history for this article is available at <https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/ele.70117>.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.

Appendix to: The assumptions of the Tea Bag Index and their implications; A reply to Mori 2024

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Appendix 1: Extended method and analysis on the timeseries dataset

Appendix 2: Re-evaluating the data of Sarneel *et al.* (2024) when keeping a large mass margin for rooibos tea

Appendix 3: Box S1; list of terms

Appendix 1: Extended method and analysis on the timeseries dataset

The used dataset consists of 32 timeseries of mass losses observed for rooibos and green tea under different conditions (Table S1). The dataset consists mainly of tea from nonwoven bags, but for 18 time series, the tea was placed in hand made woven bags. Given this heterogeneity, we included all bag types in the analysis.

For each tea type at each condition, we fitted a logistics regression and extracted the observed initial decomposition rate (k_{real} ; consistent with the terminology in Mori, 2024) as well as the observed asymptote ($asymptote_{real}$). We calculated the Tea Bag Index (TBI) for the datapoint that was closest to 90 days. We used Nonlinear Least Squares (R version 4.3.1) to fit the mass fraction remaining by $a \cdot e^{-k \cdot t} + (1-a)$, where a is the observed asymptote ($asymptote_{real}$), k is the observed initial decomposition rate (k_{real}) during the time period of the observation (t ; days). The TBI proxies were fitted following Keuskamp *et al.* (2013), on the timestep closest to 90 days (Table S1).

The relation between the observed $asymptote_{real}$ in rooibos and green tea was tested using a linear model with $asymptote_{real}$ in rooibos as the dependent parameter in R version 4.3.1 (R Core Team 2023). Likewise, the relation between the TBI asymptote of green tea (equalling the mass remaining of green tea at 90 days) and $asymptote_{real}$ in rooibos was determined.

To quantify the sensitivity of k_{real} and $asymptote_{real}$ to the duration of the incubation series, we calculated those proxies on the full time series (90-120 days) as well on time series where we removed all measurements that were longer than 60 days. We averaged k_{real} and $asymptote_{real}$ across all timeseries where fits were obtained in both the longer and short time series (Figure 2a).

For each mass remaining at 90 days, for both the timeseries dataset described here as well as the dataset used by Sarneel *et al.* (2024), we used the mass for rooibos tea observed at the time when k_{TBI} was calculated to estimate how close this observation is to the asymptote (mass margin; Box 1). For the time series dataset, we used the observed asymptote as derived from our nonlinear least squares analysis, and for the dataset in Sarneel *et al.* (2024), we used S_{TBI} to estimate the asymptote for rooibos. In addition, we calculated the difference between $asymptote_{TBI}$ and $asymptote_{real}$ of green tea and between k_{TBI} and k_{real} , to visualize how the mass margin related to the predictive power of the TBI_S and TBI_k , respectively.

Next to k_TBI (Keuskamp et al. 2013), we calculated two other initial decomposition rates using the rooibos mass remaining at ca. 90 days and following the TBI formula's. However, we substituted the asymptote based on S_TBI by 1) the observed *asymptote_real* in rooibos, and 2) by an estimated asymptote based on the empirical relation between green tea mass remaining (which equals the asymptote of green tea in the TBI model) and *asymptote_real* in rooibos. The empirical relation between green tea mass remaining and *asymptote_real* is described as $asymptote_rooibos = 1.135 * mass\ remaining\ green + 0.233$.

We also explored the role of parameterization by calculating k_TBI and S_TBI using the hydrolysable fractions described in Hayes *et al.* (2024), with $H = 0.7967$ and 0.6352 for green tea and rooibos, respectively

Table S1: Overview of the dataset presented in Fig 2 and 3. The table indicates the source, a general description of the incubation conditions, the type of tea used (with W for woven, NW for non-woven, PB for plant based, and W/NW tea from nonwoven bags placed in woven bags), if the initial mass of the bags was determined by oven drying (at ca 60/70C) or by subtracting a correction for moisture from the initial mass, the number of replicates per timestep (n), the number of timesteps included, and for which duration (in days) the k_TBI and S_TBI were calculated and lastly, an indication for which of the timeseries the model could not be fitted in R or the calculation of the TBI proxies failed. Sources are 1: Duddigan *et al.* (2020), 2: Keuskamp *et al.* (2013), 3: Mori (2022b), 4: Mori (2022a), 5: Middelani *et al.* (2023) and 6: Sarneel (unpublished).

Source	General conditions	Mesh	initial	n	Time steps	TBI duration	Failure
1	20 C, fertile soil	W	dried	3	14	91	
2	15 degrees, forest soil	W	none	6	7	68	
2	25 degrees, forest soil	W	none	6	7	68	
3	Unknown	W/NW *	dried	1	7	90	
3	Unknown	W/NW *	dried	1	7	90	
3	Unknown	W/NW *	dried	1	7	90	
3	Unknown	W/NW *	dried	1	7	90	
3	Unknown	W/NW *	dried	1	7	90	
3	Unknown	W/NW *	dried	1	7	90	
3	Unknown	W/NW *	dried	1	7	90	
3	Unknown	W/NW *	dried	1	7	90	
3	Unknown	W/NW *	dried	1	7	90	
3	Unknown	W/NW *	dried	1	7	90	
4	3C, moist	W/NW *	dried	1	6	90	
4	25 C, dry	W/NW *	dried	1	6	90	fit, k_TBI
4	3C, moist	W/NW *	dried	1	6	90	
4	25 C, dry	W/NW *	dried	1	6	90	
4	3C, moist	W/NW *	dried	1	6	90	
4	25 C, dry	W/NW *	dried	1	6	90	fit
4	3C, moist	W/NW *	dried	1	6	90	
4	25 C, dry	W/NW *	dried	1	6	90	fit
5	14 C, moist	W	dried	3	4	90	fit
5	14 C, moist	NW	dried	3	4	90	fit, k_TBI
6	10 C, moist potting soil	NW	none	5	5	99	
6	20 C, moist potting soil	NW	none	5	5	99	
6	10 C, dry potting soil	NW	none	5	5	99	
6	20 C, dry potting soil	NW	none	5	5	99	
6	18C, potting soil	PB	none	2-4	5	90	
6	18C, potting soil	PB	dried	2-4	5	90	
6	30 C, moist soil/sand	NW	none	8	6	84	
6	15 C, moist soil/sand	NW	none	8	4	84	
6	2 C, moist soil/sand	NW	none	8	5	84	

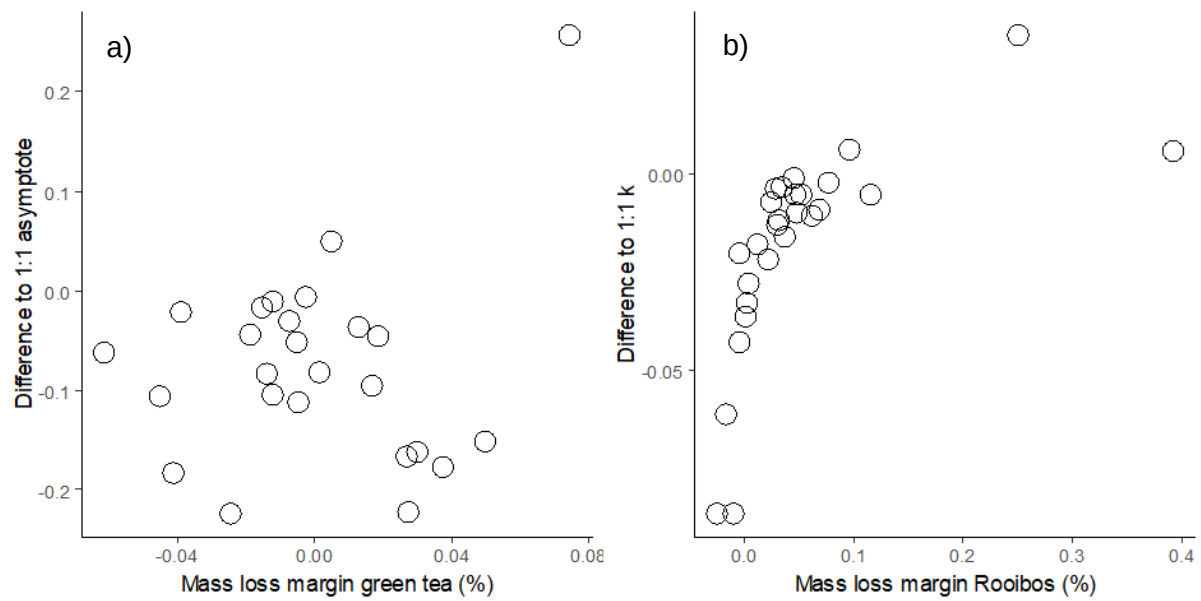


Figure S1: Deviations from the 1:1 line of the TBI-predicted and observed asymptotes of green tea (residues) in relation to the mass margin of green tea (a). In (b) absolute differences between predicted and observed initial decomposition rate of rooibos tea (residues) are given showing in relation to the mass margin of rooibos indicating how far the decomposition curve has approached the asymptote of rooibos tea. In other words, the mass margin indicates whether assumption 2 is violated or not. Because the relation is not linear in b) visual inspection suggest that the mass margin of rooibos requires to be around 10% to predict the observed k_{real} . Note that the scale of a and b are different orders of magnitude.

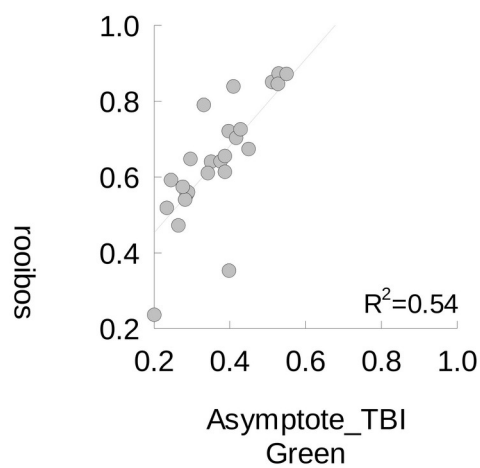


Figure S2: Empirical estimation of the asymptote of rooibos based on the relation between the green tea asymptote as described by TBI (equalling the mass remaining at 90 days) and the observed asymptote in rooibos. The relation is described by $\text{asymptote rooibos} = 1.135 * \text{asymptote TBI of green tea} + 0.233$, where the asymptote of green tea is defined by the mass fraction remaining in green tea after 90 days, which, given the small mass margin of green tea is a valid assumption.

Effect of parametrization on the relation between predicted and observed decomposition dynamics.

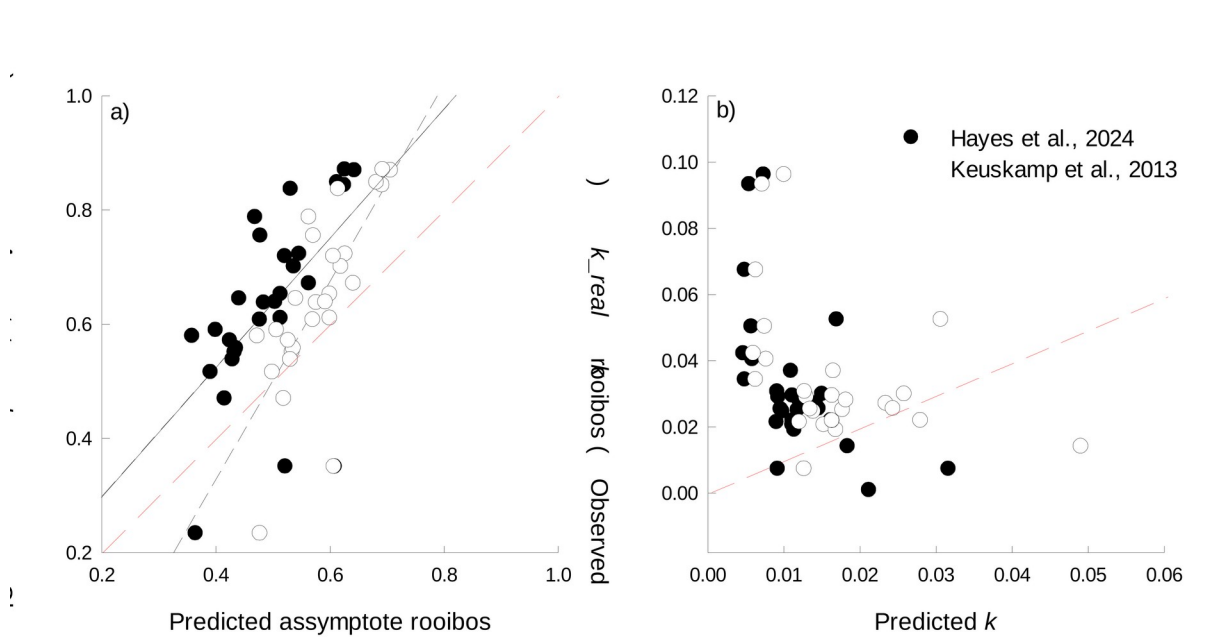


Figure S3: Using a different parameterization of the unhydrolysable fraction of rooibos and green tea does not change the mismatch observed between calculated and observed asymptote (a) and initial decomposition rate (b) of rooibos tea. The predicted asymptote was calculated following the procedure described in Keuskamp *et al.* (2013), either using the original hydrolysable fraction (white dots; $H = 0.842$ and 0.552 for green tea and rooibos respectively) or using the hydrolysable fraction described in Hayes *et al.* (2024), with $H = 0.7967$ and 0.6352 for green tea and rooibos respectively. Each point represents one timeseries and the red line indicates the 1:1 line, while the black lines indicate fitted regression lines.

Appendix 2: Re-evaluating the data of Sarneel *et al.* (2024) when keeping a large mass margin for rooibos tea

Since analyses in Appendix 1 suggest that a mass margin of ca 10% is needed for TBI_k to reflect the observed k_{real} , we re-ran the analyses presented in Sarneel *et al.* (2024) using only the data where the mass margin for rooibos is >10% (taking into account S_{TBI}). Removing these observations slightly changed the range of observed values (Figure S3). We explored if there were consistent differences between the two categories of measurements and show both the original figures as well as the updated figures of our re-analysis. In general, we did not find systematic differences that could explain conditions under which the mass margin becomes too small (Figure S4). Re-analysis of the patterns described by Sarneel *et al.* (2024) decreased the absolute values of k_{TBI} , but the patterns across large gradients remained the same (Figure S5, S6).

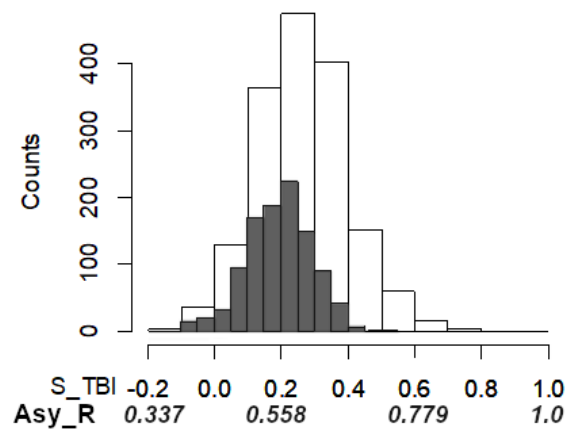


Figure S4: Distribution of S_{TBI} values in the original dataset of Sarneel *et al.* (2024) indicated with white bars and in the dataset where all the observations with a mass margin of less than 10% in rooibos have been removed (dark shaded bars). On the x-axis, the S_{TBI} values are indicated as well as the associated predicted asymptote of rooibos tea (Asy_R) based on this S_{TBI} .

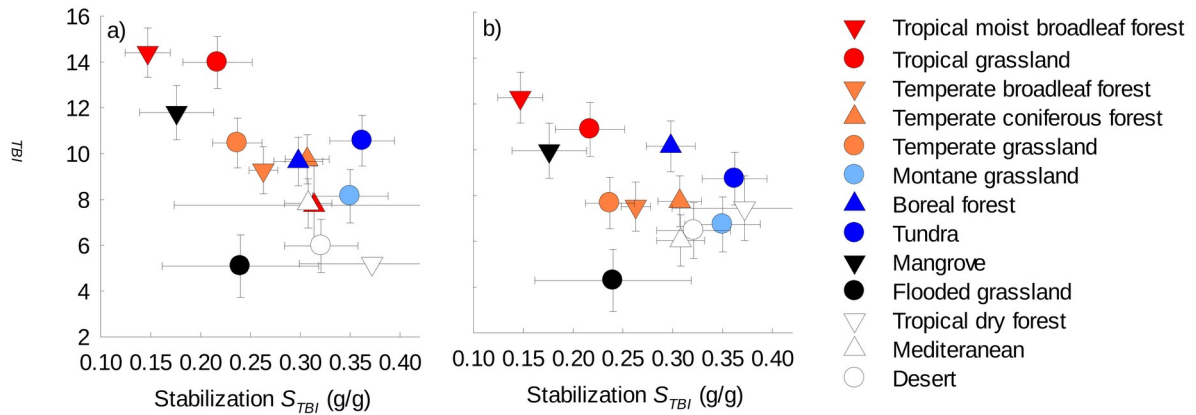


Figure S5: Mean k_{TBI} and S_{TBI} per biome as presented in a) Sarneel *et al.* (2024) and b) when removing measurements with a mass margin smaller than 10% in rooibos. “Colour coding follows main climatic conditions, with red for tropical, orange for temperate, blue for cold, black for wetlands and white for dry ecosystems. Forest biomes are indicated by triangles and low vegetation system by circles. Values shown are corrected for spatial autocorrelation” as described in Sarneel *et al.* (2024). Error bars are standard errors. Biome names follow Olson *et al.* (2001) with abbreviations as in Sarneel *et al.* (2024).

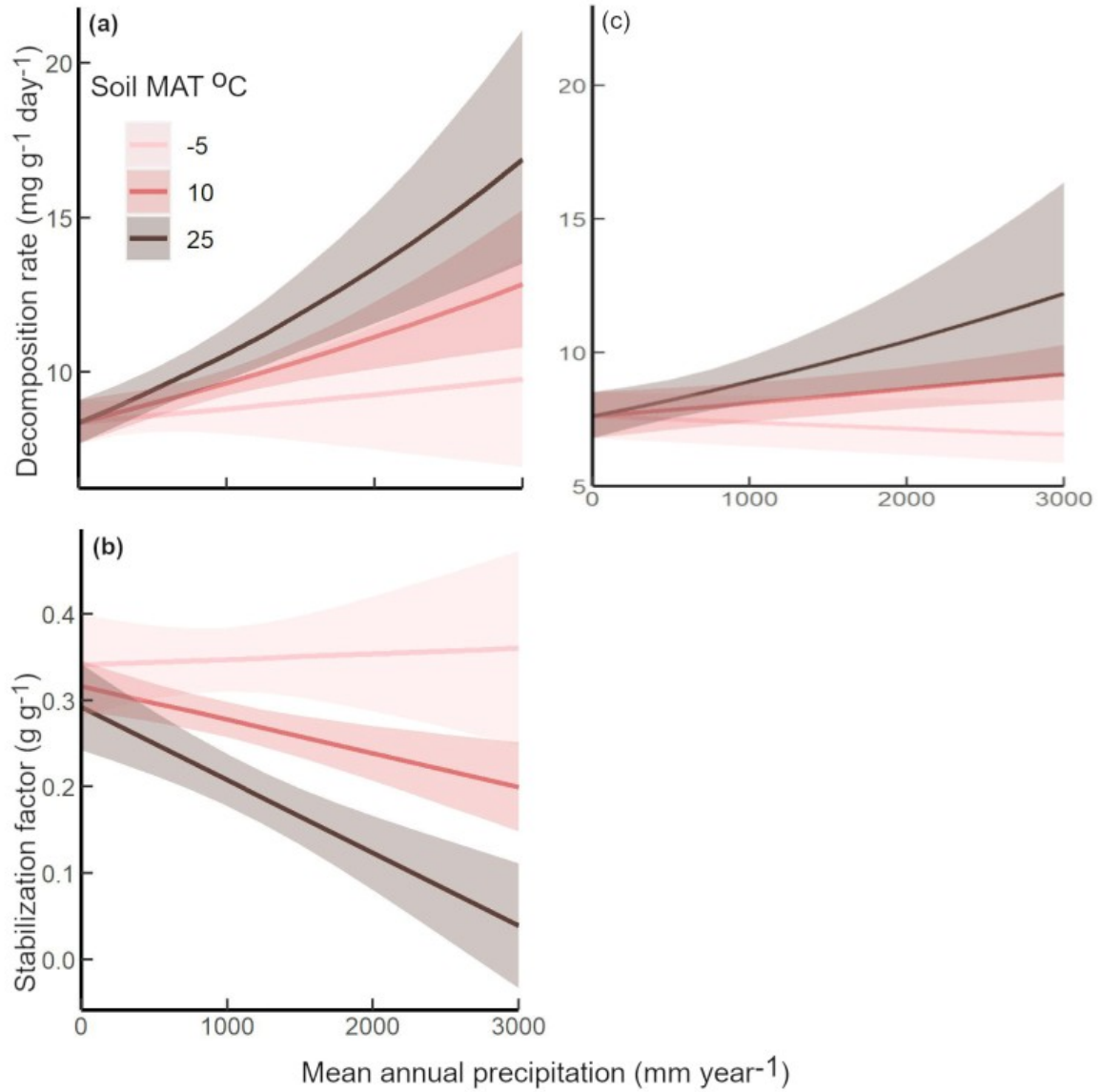


Figure S6: The interaction of both k_{TBI} and S_{TBI} with Mean Annual soil Temperature (MAT) and Mean Annual Precipitation (MAP) causes decoupling in dryer and colder environments. Relationship between mean annual precipitation (MAP) and k_{TBI} (a) S_{TBI} (b) for different values of mean annual soil temperature, based on the models described in Sarneel *et al.* (2024) and c) for the re-analysis taking only measurements with a large mass margin into account ($>10\%$). Lines indicate the mean and the shaded areas the confidence intervals obtained using 'predictSE.gls' in the AICcmodavg package in R.

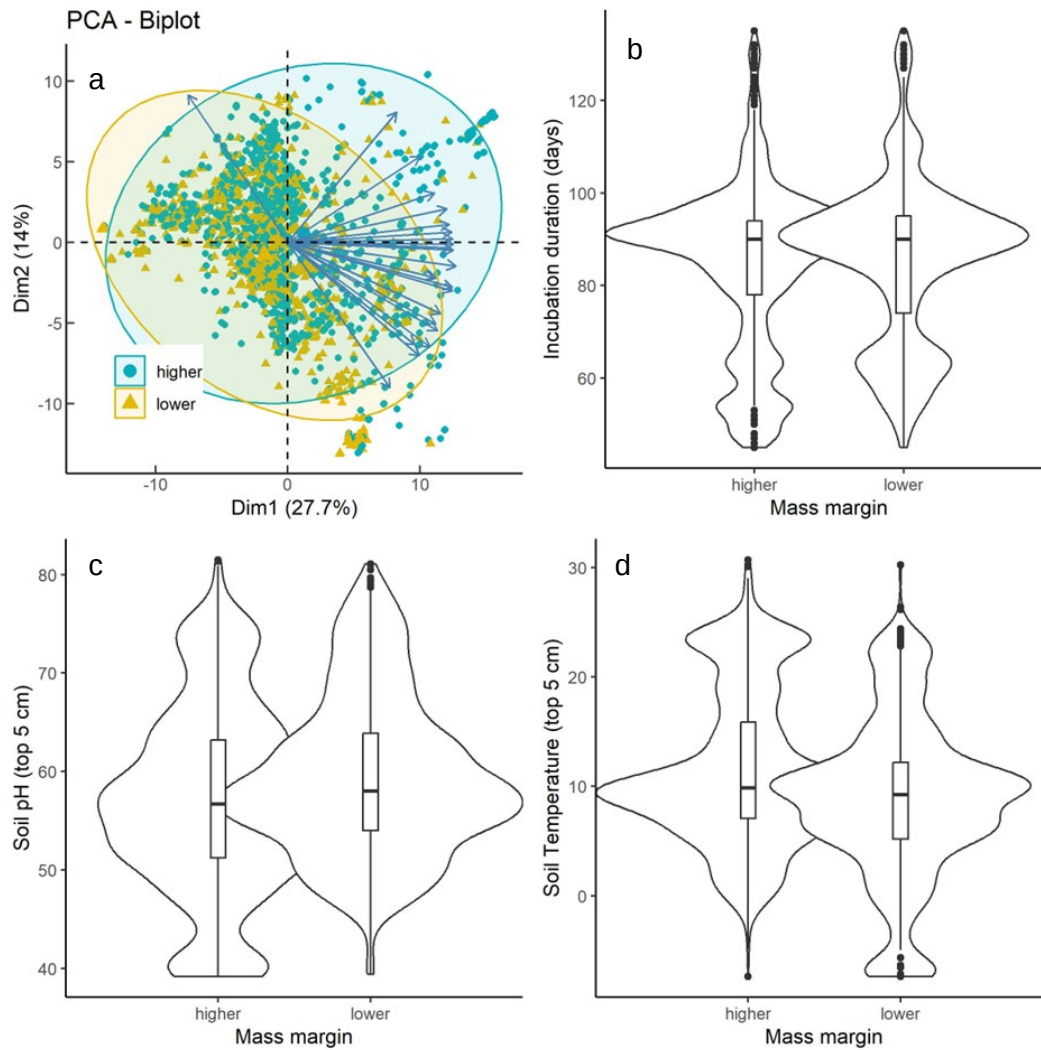


Figure S7: a) PCA plot (See Sarneel *et al.* 2024 for a description of the parameterspace) with yellow points indicating measurements where the mass margin of rooibos was <10% (lower), and blue points for measurements with a mass margin larger than 10% (higher). The distribution and median for b) incubation duration, c) Soil pH in the top 5 cm based on water extractions and derived from <https://www.soilgrids.org> as well as d) mean annual soil temperature derived from Lembrechts *et al.* (2022). The analysis in Figure S4 and S5 are based on the data in the 'higher' category.

Box S1 List of terms

Asymptote_TBI: For rooibos this encompasses the unhydrolyzable fraction plus the stabilized fraction of the hydrolysable fraction (H) rooibos. For green tea, the *asymptote_TBI* equals the mass fraction remaining at 90 days. Conceptually representing (1-a) in eq. 2 and calculated by using the stabilization factor (*S_TBI*):

$$Asymptote_{TBI(rooibos)} = 0.552 * S_{TBI} + 0.448 \quad \text{eq. 1}$$

Asymptote_real: Observed asymptote in timeseries. That is, the measured mass fraction at which the mass loss curve is observed to level off. It can be observed for green tea and rooibos separately. Conceptually representing (1-a) in eq. 2.

Asymptote_empirical: Predicted asymptote of rooibos as derived from the relation between mass fraction remaining of green tea and the observed *asymptote_real* of rooibos tea given by: $asymptote_empirical = 1.135 * asymptote_TBI \text{ green tea} + 0.233$, where *asymptote_TBI* green tea is defined by the mass fraction remaining at the time point of measuring.

Decomposition model: The Tea Bag Index (TBI) is based on the decomposition model for early-stage decomposition of fresh litter described by Wieder and Lang (1982), which characterizes an exponential decay towards an asymptote (eq. 2), reflecting varying decomposition rates among material fractions. As the TBI focuses on the initial phases of decomposition, mass loss is predominantly driven by the rapid decomposition of the most labile fraction, while the rates for more recalcitrant fractions are minimal

$$M_t = a e^{-kt} + (1-a) \quad \text{eq. 2}$$

Hydrolysable fraction (H): Fraction of fresh litter that are dissolved in the Soxhlet procedure (*H* green tea= 0.842 ; *H* rooibos = 0.552 , Keuskamp *et al.*, 2013). This fraction is interpreted as potentially hydrolysable (labile) and comprises the labile and the stabilized fraction.

k_TBI: Decomposition rate estimated following the TBI method, describing the mass loss dynamics of the labile fraction following eq. 2. In short, it is calculated at 90 days of incubation by scaling *S_TBI* and resolving eq 2. using the observed mass loss of rooibos. Equivalent to k_{1TBI} (Sarneel *et al.* 2024). For this work, we recalculated *k_TBI*, once by using the *asymptote_real* of rooibos and second by using *Asymptote_empirical*, by substituting those for (1-a) in eq 2.

k_real: Observed decomposition rate derived from time series (Appendix 1) using Nonlinear Least Squares models.

Labile fraction (a): Easy to decompose material. Described by decomposition rate constant (*k*). For TBI, *a* is quantified by the mass loss fraction observed in green tea after 90 days.

Mass margin (MM): The difference between the observed mass fraction remaining at 90 days and observed *asymptote_real*, Indication how far decomposition has advanced to the asymptote. Can be calculated for both rooibos and green tea time series as well as field data on rooibos tea when replacing *asymptote_real* by its best approximation (*asymptote_TBI*):

$$Mass\ margin = Mt - Asymptote_{real\ rooibos} = Mt - Asymptote_{TBI} \quad eq. 3$$

Stabilized fraction: The part of H that becomes stabilized and more recalcitrant to decomposition.

Stabilization factor (S_{TBI}): The stabilized fraction is scaled to the size of the hydrolysable fraction. S_{TBI} is equivalent to S_{TBI} (Sarneel et al. 2024) and S (Keuskamp et al. 2013) and quantified as:

$$S_{TBI} = 1 - \frac{a_g}{H_g} \quad eq. 4$$

Unhydrolyzable, or acid-insoluble, fraction: The fraction of fresh litter that is not soluble in fat, water or acid and is left after the Soxhlet extraction (green tea: 0.258; rooibos: 0.448; Keuskamp et al., 2013). This material is considered to be recalcitrant to decomposition and contains a high proportion of lignified material.

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