Soil is the New Teapot: How Tea Bags Tell Us About Global Carbon Cycling

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Abstract

Polar biomes are generally described as having low decomposition rates due to cold soils. With global warming the soils are expected to warm, and soil decomposition rates may increase. These changes could potentially shift the carbon balance of arctic tundra ecosystems from carbon sinks to sources. To better understand and document decomposition rates, an international effort has created a standardized protocol, the Tea Bag Index (TBI), to calculate decomposition rates (*k*) and sequestration potentials (*S*) in any ecosystem. We used the TBI at two sites in northern Alaska and found that both locations had higher *S* values than previously studied ecosystems, indicating that tundra ecosystems may function as carbon sinks. However, *k* values were higher than anticipated, although values were still lower than in most biomes. This suggests that the sites metabolize a smaller fraction of organic matter compared to any biome but that the rate of this breakdown is similar to other ecosystems.

Methods

This study was conducted at Utqiaġvik (formerly Barrow) and Atqasuk in northern Alaska (**FIG. 1**). At both locations a 100 point grid approximately 1 km^2 was established in the early 1990s to monitor ecosystem change. At a subset of 30 plots spanning all community types, we buried tea bags following the Tea Bag Index (TBI). These methods are described fully in Keuskamp et al. (*Methods in Ecology and Evolution*, 2013).

FIG 1. Locations of Utqiaġvik and Atqasuk, Alaska. Both locations are within the low arctic tundra region and have a long history of environmental research.

Field Methods: To calculate stabilization factor (*S*) and decomposition rate constant (*k*) values, green and rooibos tea bags (Lipton, Unilever, **FIG. 3**) were marked, weighed, then buried for the duration of the field season. Three bags of each tea type were buried at each of the 30 plots within the grid subsets. During incubation, soil temperature, soil moisture, and active layer depth were measured approximately every other week. At the end of the field season, tea bags were retrieved, oven-dried, then reweighed to determine final weights.

Methods (cont.)

Mathematics: Due to differences in decomposition rates, green and rooibos tea can be used to simultaneously determine decomposition rate constants (*k*) and stabilization factors (*S*) (Keuskamp et al., 2013; **FIG. 2**).

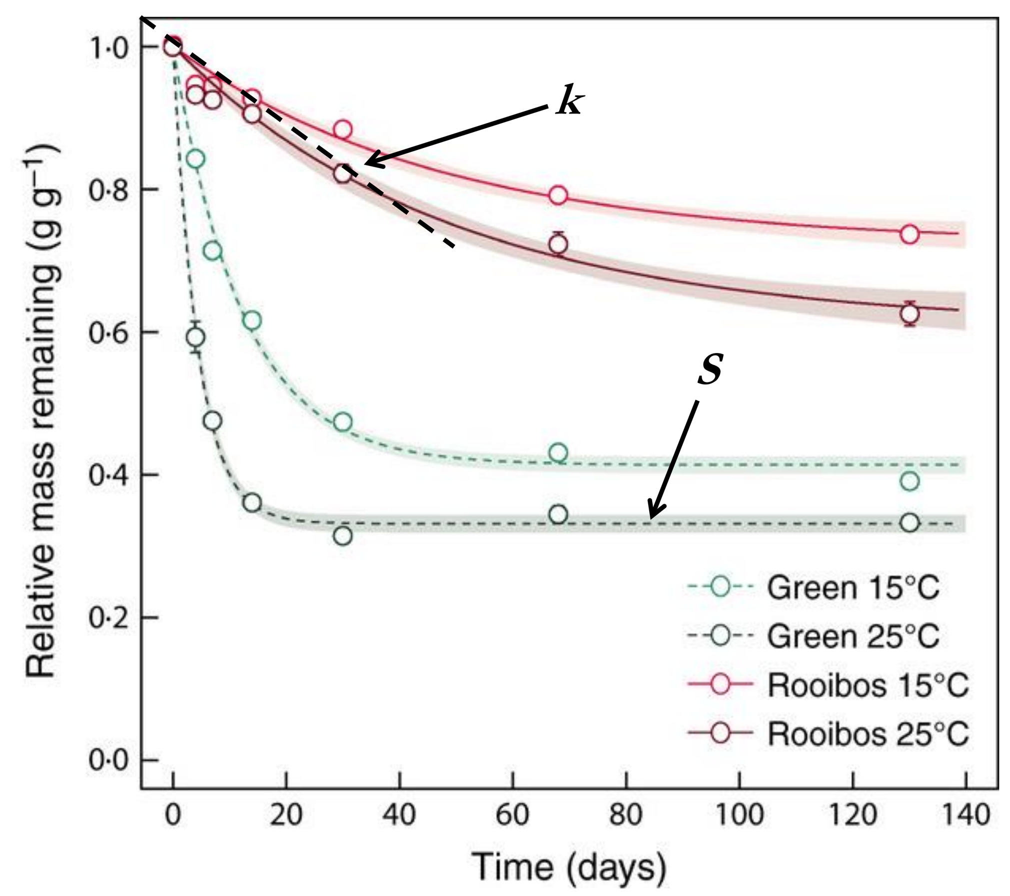

FIG 2. Decomposition trends of green and rooibos tea.

The two-stage decomposition process of these teas can be summarized by the expression:

$$W(t) = ae^{-kt} + (1-a)$$

where *W(t)* is the weight after incubation time *t*, *a* and *1-a* are the labile and recalcitrant fractions respectively, and *k* represents the decomposition rate constant of the labile fraction. Using green tea we can calculate *S* using the equation:

$$S = 1 - \frac{a}{H}$$

where *a* is the observed labile fraction and *H* is the potential labile fraction. By calculating *S*, we can determine the labile fraction of rooibos tea (a_r) using the equation:

$$a_r = H_r(1-S)$$

where H_r is the potential labile fraction of rooibos tea. Using a_r, we can then calculate *k* using the first equation above.

FIG 3. Lipton (Unilever) rooibos and green tea bags serve as ideal substitutes for traditional litter bags.

Results

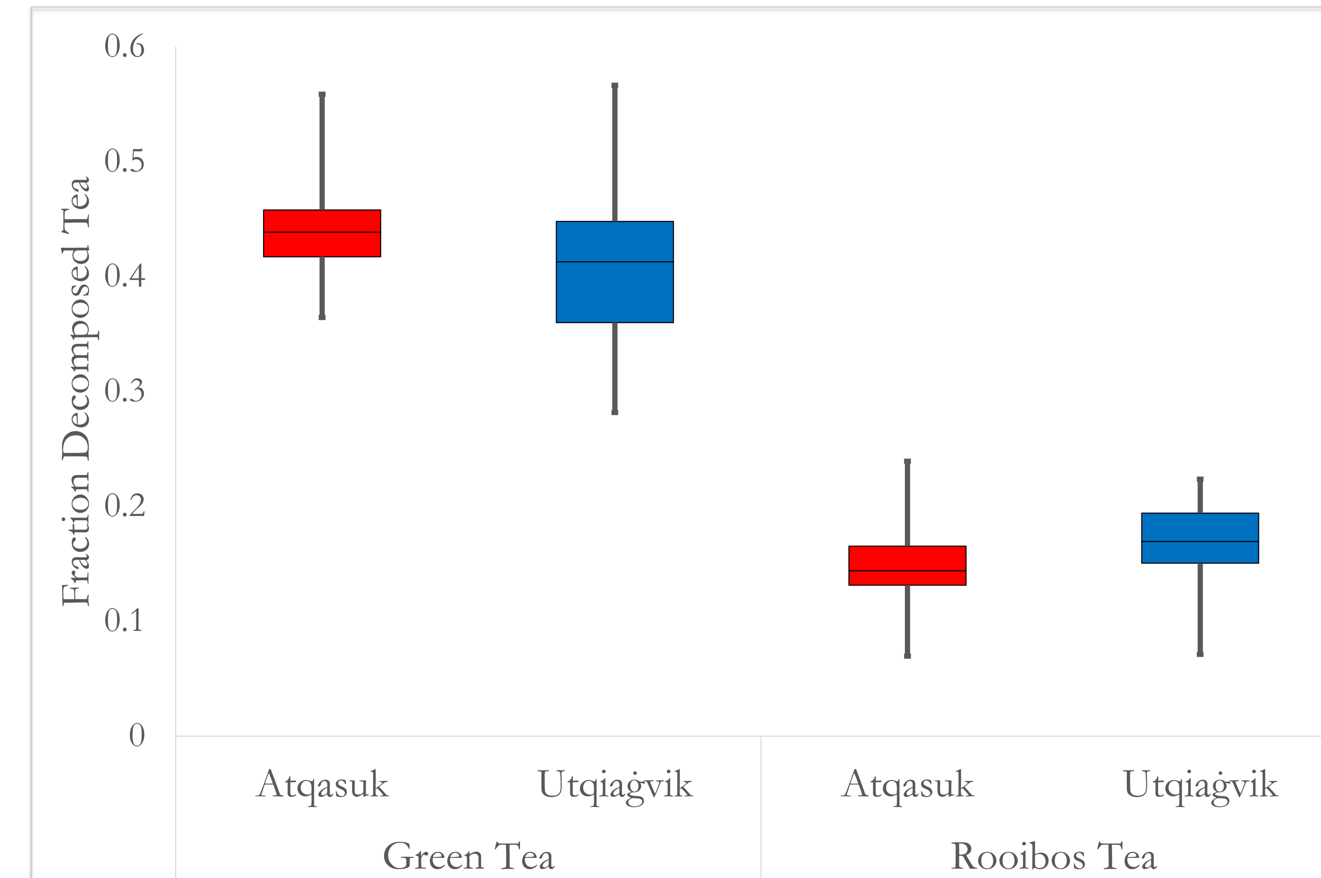

FIG 4. Fractions of green and rooibos tea that decomposed at Atqasuk and Utqiaġvik. Green tea decomposed significantly more than rooibos, confirming the trend established by Keuskamp et al. (2013).

The green and rooibos tea decomposed differently as predicted (**FIG. 4**). Green tea decomposed significantly more than the rooibos tea ($p<0.001$ for both sites), consistent with lab procedures conducted by Keuskamp et al. (2013). Additionally, calculated *S* and *k* values were consistent with global temperature and precipitation trends (**FIG. 5**). However, trends were not consistent on a smaller scale when comparing the two sites (i.e., higher *k* values in Utqiaġvik than Atqasuk).

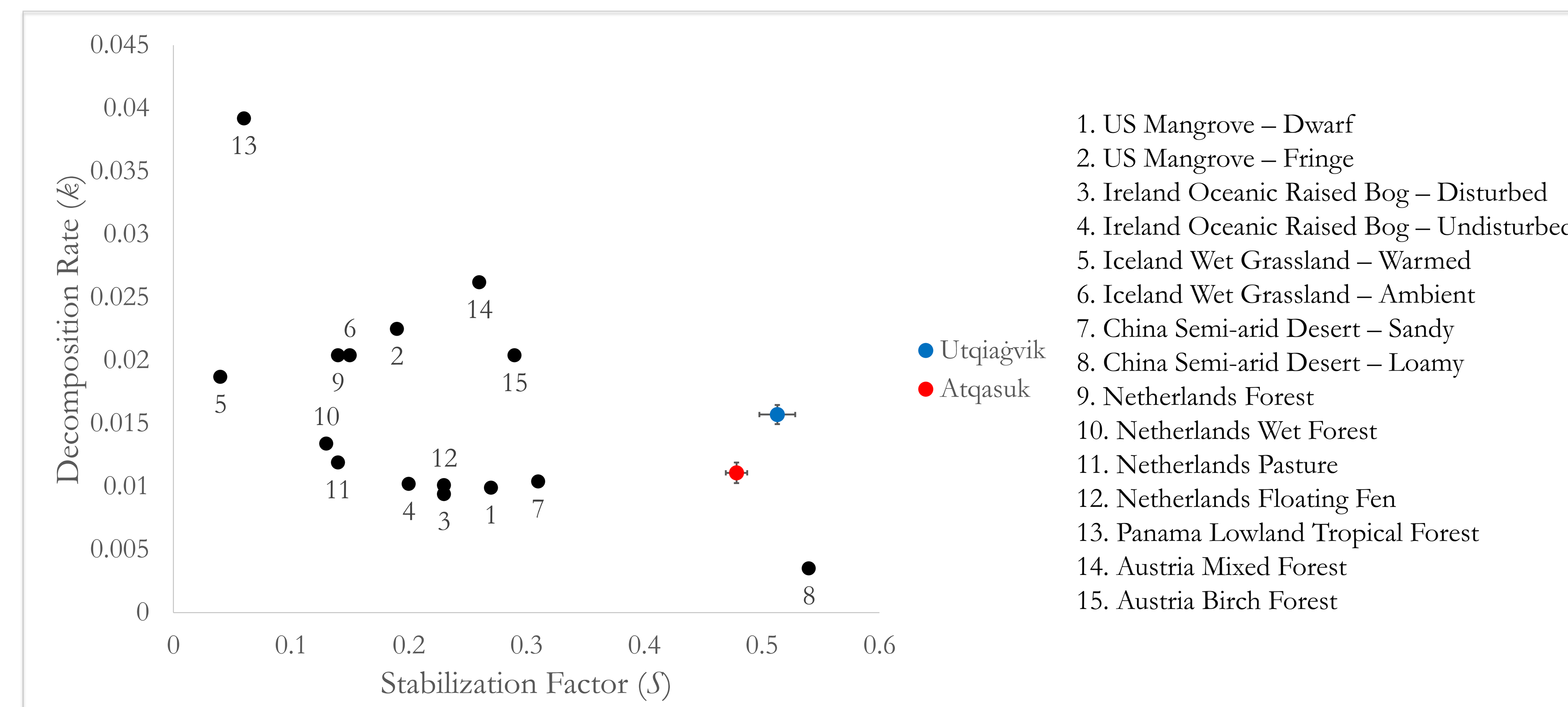

FIG 5. Calculated *S* and *k* values for Atqasuk and Utqiaġvik relative to previously calculated values in other biomes. Previous work determined calculations at site 8 were inaccurate due to low microbial activity (Keuskamp et al., 2013).

Conclusions

The Tea Bag Index (TBI) was successfully used to determine the stabilization factor *S* and decomposition rate constant *k* at Utqiaġvik and Atqasuk. The calculated values indicate that these sites sequester higher proportions of carbon than any previously studied site, while initial decomposition rates are similar to other biomes.

However, further work ought to be done to determine if incubation times are long enough to avoid overestimations of *S*, which in turn may lead to underestimations of *k*. Once this potential issue is resolved, continued use of this method can track changes in the carbon balance of tundra ecosystems.

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