

# Forest litter decomposition in the Northern Hemisphere – evaluation of alternative approaches to model the effects of climate

## Background

Climate is an important factor regulating litter decomposition. To estimate the carbon balance of this remarkable pool in the forests of the Northern Hemisphere, a reliable yet operational model of the climatic effects is needed. "Reliable" refers to quantifiable and small uncertainty in decomposition rate estimates of different litter types. In this study, we evaluated the reliability of alternative climate-effect models across the Northern forests.

## Material and methods

We used mass loss measurements of 16 foliar litter types (a subset of all litter types) taken at 68 study sites across North America and Europe as a part of the CIDET<sup>1</sup>, LIDET<sup>2</sup> and EuroDECO<sup>3</sup> networks (Figs. 1 and 2). Altogether, the data consisted of 5355 data points in time series varying from 3 to 10 years in length.

We assumed exponential mass loss over time and consequently fitted the following equations to the data by litter type

$$m(t, C_1) = e^{at+btC_1} \text{ and } m(t, C_2, C_3) = e^{at+btC_2+ctC_3}$$

where  $m$  denotes mass fraction remaining at time  $t$  ( $m = 1$  at  $t = 0$ ),  $C_i$  climate variables ( $C_1$ =DEFAC climate index (annual average of monthly temperature and moisture effects as used e.g. in the CENTURY model), actual evapotranspiration (AET) or mean annual temperature (MAT), and  $C_2$ =MAT and  $C_3$ =mean annual precipitation (MAP)), and  $a$ ,  $b$  and  $c$  fitted parameters.

## Results

The DEFAC, AET and MAT+MAP models gave decomposition estimates that were almost similar in accuracy for each litter type (Fig. 3); the  $r^2$  values averaged over the litter types were 0.69, 0.68 and 0.63, respectively. The  $r^2$  values of the MAT alone model were equally high for 11 litter types out of 16 but lower for the other 5.

Despite of the similar  $r^2$  values, the probability distributions of the fitted parameters were remarkably different between the models (Fig. 4).

For the DEFAC model (Fig. 4a), the intercept (parameter  $a$ ) and the DEFAC effect (parameter  $b$ ) were correlated with the values of many litter types overlapping. In addition, the parameter values were systematically lower when estimated from the LIDET than the CIDET data. The MAT+MAP model did not separate the litter types at all (Fig. 4b). For the MAT alone model (Fig. 4c), the parameter values were least correlated, showing greater separation among litter types and the parameter values independent of the dataset.

The correlations between the parameter values of a model make an uncertainty analysis of the results difficult. The overlap among litter types indicates inadequacy of any model with climate effects alone, since different litter types are known to decompose at different rates. The dependency of the parameter values on data origin suggests a systematic difference in the calculations of the DEFAC climate index.

## Conclusions

Temperature explains the majority of variability in decomposition rates across the region studied. The various ways of accounting for moisture effects marginally improved the  $r^2$  values for most of the litter types but complicated the probability distributions of the parameter values and consequently any uncertainty analysis on the results.

$r^2$  values are inadequate criteria to evaluate the reliability of litter decomposition models. The reliability of model-calculated decomposition estimates depends essentially on the probability distributions of the parameter values.

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Finnish Environment Institute  
Research Programme for  
Global Change  
P.O.Box 140, FIN-00251  
Helsinki, Finland  
firstname.lastname@ymparisto.fi

Liski, J.<sup>1</sup>, Tuomi, M.<sup>1, 2</sup>, Palosuo, T.<sup>3</sup>, Parton, W.J.<sup>4</sup>, Adair, C.<sup>5</sup>,  
Trofymow, T.<sup>6</sup>, Smyth, C.<sup>6</sup>, Berg, B.<sup>7</sup> & Johansson, M.-B.<sup>8</sup>

1 Finnish Environment Institute, Research Department, Research Programme for Global Change, Helsinki, Finland  
2 Department of Mathematics and Statistics, University of Helsinki, Finland  
3 European Forest Institute, Joensuu, Finland  
4 Natural Resource Ecology Laboratory, Colorado State University, USA  
5 Department of Forest Resources, University of Minnesota, USA  
6 Pacific Forestry Centre, Canadian Forest Service, Natural Resources Canada, Canada  
7 Department of Forest Ecology, University of Helsinki, Finland  
8 Department of Forest Soils, Swedish University of Agricultural Sciences, Sweden

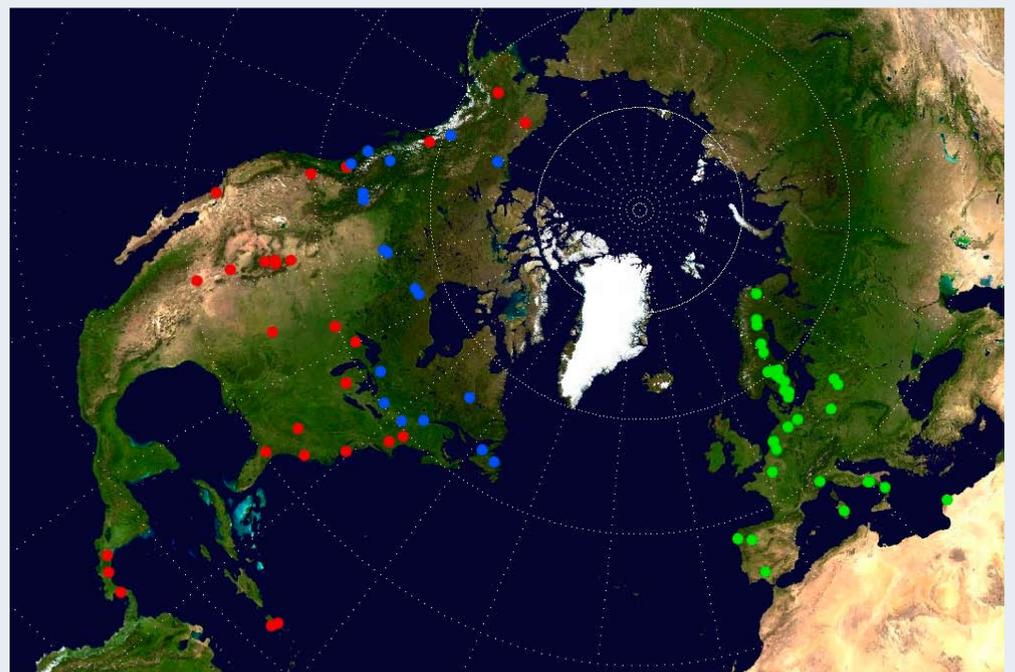


FIG 1: The study sites (CIDET blue, LIDET red, EuroDECO green).



FIG 2: Litter bags used for the mass loss measurements. A photo from a EuroDECO site.

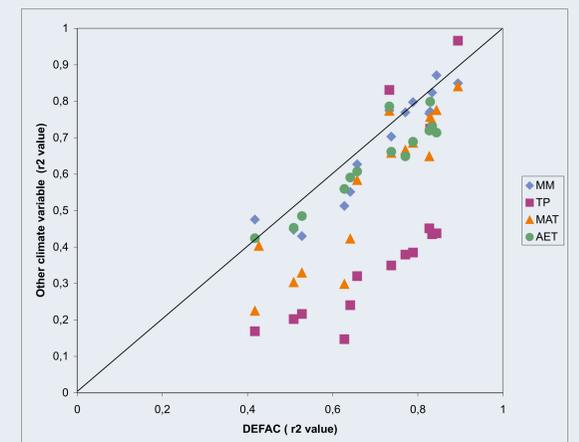


FIG 3:  $r^2$  values of the climate-effect models compared to those of the DEFAC model. A mark represents a litter type average.

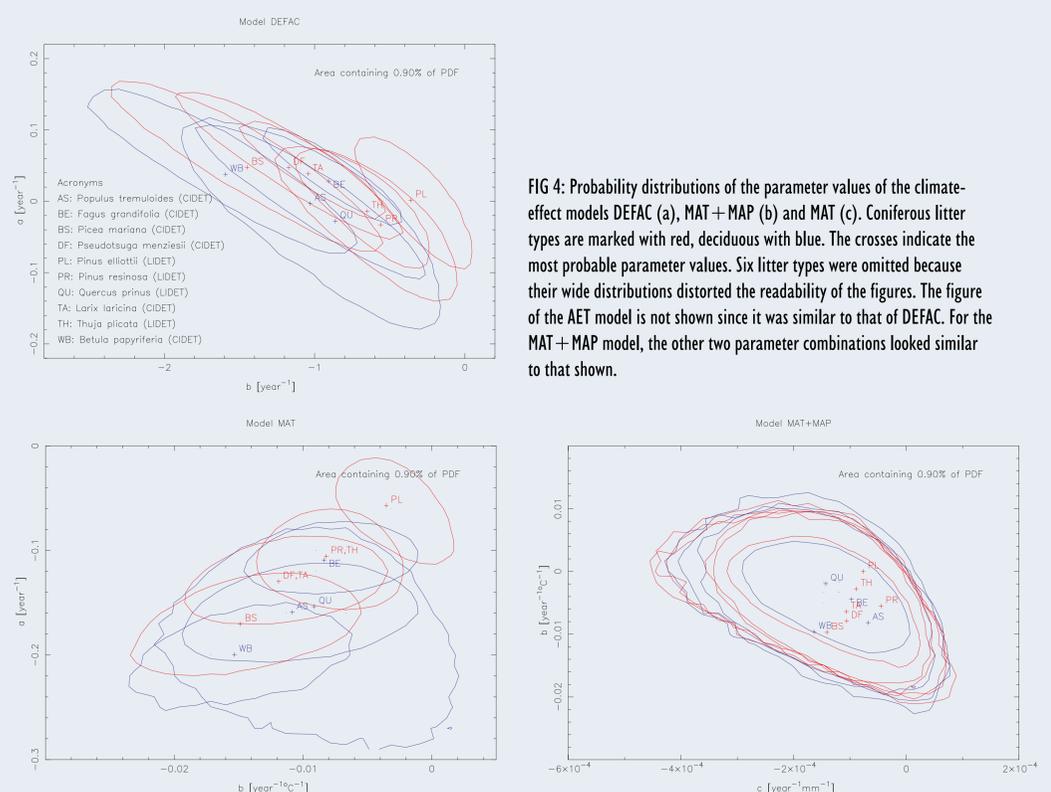


FIG 4: Probability distributions of the parameter values of the climate-effect models DEFAC (a), MAT+MAP (b) and MAT (c). Coniferous litter types are marked with red, deciduous with blue. The crosses indicate the most probable parameter values. Six litter types were omitted because their wide distributions distorted the readability of the figures. The figure of the AET model is not shown since it was similar to that of DEFAC. For the MAT+MAP model, the other two parameter combinations looked similar to that shown.