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Ecological Modelling 189 (2005) 183–198
ECOLOGICAL MODELLING
www.elsevier.com/locate/ecolmodel

Litter decomposition affected by climate and litter quality—Testing the Yasso model with litterbag data from the Canadian intersite decomposition experiment

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Received 25 August 2004; received in revised form 3 February 2005; accepted 29 March 2005
Available online 31 May 2005

Abstract

Litterbag experiments provide valuable data for testing the accuracy of predictions of decomposition from soil carbon models. The soil carbon model Yasso describes litter decomposition based on basic climate and litter quality information, and was calibrated using European litterbag data. In this study, we tested the predictive capabilities of Yasso using independent litterbag data for 10 foliage litter types decomposed for 6 years at 18 upland forest sites across Canada (CIDET).

The model underestimated mass of leaf litters remaining on CIDET sites, with only a small systematic error in predicting the effects of climate when effective temperature sum was used as the temperature variable in the model. The overall rate of decomposition was predicted correctly when mean annual temperature was used as the temperature variable, but then the model substantially overestimated climatic effects.

The model correctly predicted differences in decomposition rates among litter types in the early years of decomposition, but underestimated them in later years. The decomposition rate of the litter type richest in phenolic compounds (larch needles) was systematically overestimated, and that of the litter type richest in *O*-alkyl compounds (grass leaves) was systematically underestimated. Accounting for these factors would improve the general applicability of the model. However, accounting for the initial nitrogen concentration of litter did not improve the accuracy of the model unless the initial lignin (i.e., acid unhydrolyzable residue) content was also taken into account.

We conclude that the model Yasso accounts for most of the effects of climate and initial litter quality on the decomposition of a range of foliage litter types under varying climate conditions. Recalibration of the reference decomposition rates used in the model may improve the accuracy when applying the model outside of Europe.

Keywords: Dynamic model; Yasso; Decomposition; Litterbag; Soil carbon; CIDET

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doi:10.1016/j.ecolmodel.2005.03.006

1. Introduction

The sizes of soil carbon pools and rates of organic matter decomposition are crucial components of the global carbon budget (Prentice et al., 2001). Measuring decomposition rate of organic matter and carbon accumulation in soils is difficult, and models are widely used to estimate these parameters (Powlson et al., 1996). Evaluating the accuracy of such models is therefore essential if they are to be used to reliably describe soil carbon stocks and their dynamics at present and in the future.

The dynamic model Yasso was developed to be a simple but widely applicable soil carbon model requiring a limited amount of input data (Liski et al., 2005). The model has already been applied as a soil carbon module in the CO2FIX model, which is a general model for estimating carbon balance and carbon sequestration capacity in forest stands and landscapes (Schelhaas and Nabuurs, 2001; Masera et al., 2003), in forest stand simulator MOTTI (Hynynen et al., 2005) and in the forest resource projection model EFISCEN (Karjalainen et al., 2002).

Yasso takes into account differences in initial litter quality and the effect of climate on decomposition processes. The effect of climate is described using equations that include temperature and summer drought as explanatory variables (Liski et al., 2003, 2005). Either mean annual temperature (MAT) or the effective temperature sum over 0 °C threshold (DD0) can be used as the temperature variable. DD0 has been found to be an effective predictor of decomposition rate (Liski et al., 2003), whereas MAT data are usually more readily available for different study sites and areas. Summer drought is taken as the difference between the precipitation and potential evapotranspiration from May to September. The initial litter quality is considered in terms of physical size of the litter and content of different carbon compounds in the litter.

Compared to other soil carbon models, Yasso is less detailed and requires less input data than, for example, the two widely used models CENTURY (Parton et al., 1987) or RothC (Coleman and Jenkinson, 1996). It is, therefore, possible to use Yasso when there is not enough input information to use these more detailed models. On the other hand, Yasso is more general than soil carbon modules developed specifically for larger modelling systems such as the dynamic global vegetation model LPJ (Sitch et al., 2003), Canadian forest sector carbon budget model (Kurz and Apps, 1999) or a stand-level forest and wood products model GORGAM (Schlamadinger and Marland, 1996). As Yasso is an independent model, its applicability is not limited to any larger modelling framework but it may be used with any other modelling system that calculates estimates of litter production. In structure, Yasso is partly similar to models DocMod (Currie and Aber, 1997) and GENDEC (Moorhead and Reynolds, 1991); in these models litter entering soil is divided into explicit groups of chemical compounds. The CENTURY and the RothC models are different in this respect as in them this division of litter depends on chemical indicators related to its decomposability. In summary, the low requirements of input data, the general structure and the easiness to apply it for different research purposes make Yasso an attractive alternative among soil carbon models. However, as there are a number of factors that Yasso does not take into account that also affect decomposition processes, such as initial nitrogen and phosphorus contents of litter, microclimatic variation created by stand structure, and site factors such as soil chemistry, soil texture or organisms (Berg and McClaugherty, 2003), it is important to test the validity of this model and to identify the most important possibilities to improve its accuracy.

A number of long-term litterbag experiments have recently been established in which different litter types are incubated in the field under a wide range of site and climate conditions (e.g., Trofymow and the CIDET Working Group, 1998). Data from these field incubations are particularly valuable for independently testing models like Yasso for their ability to predict the effects of climate and initial litter quality on decomposition. In particular, data from the Canadian Intersite Decomposition Experiment (CIDET) (Trofymow and the CIDET Working Group, 1998) allow for independent testing of Yasso under Canadian climatic conditions which, to a certain extent, are similar to those of northern Europe where the data used to derive the original model parameter values were collected.

The objective of this study was to use the CIDET data set to evaluate how accurately the soil carbon model Yasso predicts the mass loss of different types of forest litter over 6 years, based on initial litter chemistry and climatic variables. The performance of the model was tested for two different temperature