



Sensitivity of four ecological models to adjustments in fine root turnover rate



M. Luke McCormack^{a,b,*}, Elizabeth Crisfield^c, Brett Raczka^d, Frank Schnekenburger^e, David M. Eissenstat^{a,f}, Erica A.H. Smithwick^{a,c}

^a Intercollege Graduate Degree Program in Ecology, The Pennsylvania State University, USA

^b Key Laboratory of Ecosystem Network Observation and Modeling, Synthesis Research Center of Chinese Ecosystem Research Network, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, 11A Datun Road, Chaoyang District, Beijing 100101, China

^c Department of Geography, The Pennsylvania State University, 302 Walker Building, University Park, PA 16802, USA

^d Department of Meteorology, The Pennsylvania State University, 503 Walker Building, University Park, PA 16802, USA

^e Department of Forest Ecosystems and Society, Oregon State University, 321 Richardson Hall, Corvallis, OR 97331, USA

^f Department of Ecosystem Science and Management, The Pennsylvania State University, 117 Forest Resources Building, University Park, PA 16802, USA

ARTICLE INFO

Article history:

Received 9 August 2014

Received in revised form 6 November 2014

Accepted 11 November 2014

Available online 26 November 2014

Keywords:

Root production

Carbon cycle

Ecosystem

Model sensitivity

Carbon allocation

Belowground processes

ABSTRACT

Large uncertainties surrounding root-specific parameters limit model descriptions of belowground processes and ultimately hinder understanding of belowground carbon (C) dynamics and terrestrial biogeochemistry. Despite this recognized shortcoming, it is unclear which processes warrant attention in model development, given the computational cost of additional model complexity. Here, we tested the sensitivity of four models to adjustments in fine root turnover in forested systems: CENTURY, ED2, MC1, and LANDCARB. In general, faster root turnover rates resulted in lower total system carbon (C) and within model changes ranged from 1% to 38% following 100-year simulations. However, the underlying mechanisms driving these changes differed among models as some expressed lower net primary productivity (NPP) with faster turnover rates and others had similar NPP but large shifts in C allocation away from wood to fine roots. Based on these findings we expect that different model responses to changes in fine root turnover will be determined by (1) whether C is allocated to fine roots as fixed portion of NPP or to maintain a fixed biomass ratio between fine roots and leaves or stems and (2) whether soil nutrient and water uptake is a function of both resource availability and fine root biomass or based on resource availability alone. These results suggest that better constrained estimates of fine root turnover will represent a valuable improvement in many terrestrial biosphere models.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Terrestrial biosphere models simulate a range of natural phenomena in ecosystems across the globe including basic patterns of plant growth and senescence, carbon (C) fluxes and storage, as well as aspects of nutrient and hydrological cycles. Together, these models attempt to forecast the responses of terrestrial systems to changes in local environments and global climate and may inform better management and policy decisions

(Stocker et al., 2013). However, due in large part to a lack of empirical data, many belowground processes are poorly represented in ecological models (Ostle et al., 2009; Iversen, 2010; Smithwick et al., 2014), with complex belowground behaviors (e.g., autotrophic and heterotrophic respiration, C allocation, decomposition) represented by a small set of critical parameters. Of these, fine root turnover is one of the most common parameters included in terrestrial process models and is often used to tune belowground C fluxes. Empirically, fine root turnover is the process by which live roots die and transfer C into the soil where it may be respired to the atmosphere or accrue in soil C pools. In addition to its influence on C fluxes between soil pools and the atmosphere, fine root turnover rates also affect the total amount of root standing biomass, thus potentially influencing nutrient and water uptake by plants.

While the importance of root turnover in terrestrial systems is increasingly recognized (Ciais et al., 2008; Malhi et al., 2011),

* Corresponding author at: Room 1416, Institute of Geographic Sciences and Natural Resources Research, 11A Datun Lu, Chaoyang District, Beijing, 10010, China. Tel.: +86 132 6153 4030.

E-mail addresses: mltmcc@gmail.com (M. L. McCormack), crisfield.psu@gmail.com (E. Crisfield), bmr205@psu.edu (B. Raczka), frank.schnekenburger@oregonstate.edu (F. Schnekenburger), dme9@psu.edu (D.M. Eissenstat), smithwick@psu.edu (E.A.H. Smithwick).

accurately and consistently quantifying root turnover empirically has proven difficult. Most estimates of root turnover have been derived through indirect means including sequential soil coring, in-growth core methods, and whole-system budget approaches (Dahlman and Kucera, 1965; Hendrick and Pregitzer, 1993). More recently, minirhizotrons have enabled direct observations of root dynamics and root turnover (Majdi et al., 2005; Pritchard et al., 2008a; McCormack et al., 2014) and isotopic tracers have enabled researchers to estimate the age of C in fine roots (Gaudinski et al., 2001; Matamala et al., 2003). However, data regarding turnover rates from minirhizotrons and isotopic techniques are still relatively sparse compared to coring approaches. Furthermore, while each method ostensibly measures the same process of root turnover there are indications of general bias among the different methods regarding both the method itself and the actual pool of fine roots being observed (Guo et al., 2008; Strand et al., 2008). The slowest fine root turnover rates are generally derived from isotopic methods and range from 0.1 to 0.4 yr⁻¹ (Gaudinski et al., 2001; Matamala et al., 2003), while coring approaches and minirhizotron observations tend to yield faster turnover estimates in the range of 0.3–1.5 yr⁻¹ and 0.6–3.0 yr⁻¹, respectively (Aerts et al., 1992; Gill and Jackson, 2000; McCormack et al., 2014). Some model applications have also used fine root turnover rates of 5.0 yr⁻¹ or greater under some conditions (Medvigy et al., 2009; Parton et al., 2010). Though some of the variation is due to differences across sites and species (Gill and Jackson, 2000; Yuan and Chen, 2010) it is also clear that a large portion of the variability is due to broader uncertainties regarding descriptions of fine roots and the methods used to estimate of root (Smithwick et al., 2014).

Many models operating in perennial systems include an explicit fine root pool (separate from coarse roots), though it is not always clear what exactly constitutes a fine root. In most cases, this pool is intended to represent the most metabolically active roots that are responsible for water and nutrient uptake. Historically, this has been considered as all roots ≤ 2 mm in diameter, which is reflected in biomass estimates used to parameterize most models (e.g., (Smithwick et al., 2009), though the specific cutoff may vary (e.g.,

Dymond et al., 2012). However, it is important to note that determining which roots represent active, absorptive roots is not trivial and assessing turnover rates for the most distal, absorptive fine roots separately from more proximal, transport fine roots represents a significant challenge. For example, minirhizotrons tend to be biased towards the most distal, absorptive pool of fine roots where isotopes likely capture the more transportive and persistent roots (Guo et al., 2008; Strand et al., 2008). This has resulted in a wide range in fine root turnover rates measured and reported both across and within ecosystems.

Variability in reported fine root turnover rates and limited empirical understanding of the patterns and processes controlling root turnover have made it difficult to constrain estimates of fine root turnover in models. Where sufficient data are available and relevant to a given species or study system, ecoinformatic approaches which combine information from multiple data streams may be useful in constraining parameter estimates in the future (LeBauer et al., 2013; Wang et al., 2013). However, in many systems where little to no data are available it is likely that model estimates will remain uncertain for some time. As a result, models commonly use estimates of fine root turnover that span an order of magnitude. Table 1 reports turnover rates used in 18 different models parameterized for temperate forest ecosystems, estimates for which range from 0.15 yr⁻¹ to >5.0 yr⁻¹. The large variation in turnover rates used raises questions about how these different turnover rates impact results across different models. If a model that uses a turnover rate of 0.3 yr⁻¹ instead used a turnover rate of 3.0 yr⁻¹, how would different pools of C within the modeled ecosystem change? Or, would they change at all? It is unclear how sensitive different types of models are to variation in root turnover rates.

Though differences in fine root turnover rates in natural systems have direct implications for C, nutrient, and water cycling; the sensitivity of these cycles to root turnover in models will depend largely on model structure. Two specific areas likely to impact model sensitivity to root turnover include the simulated approach to allocate C among biomass pools and the treatment of

Table 1

Review of 17 terrestrial models and their parameterization of fine root turnover in temperate forests. PFT = plant functional type.

Model	Fine root turnover	Example	Ref.
Biome-BGC	Initially set equal to leaf turnover, now can be user defined.	0.8 yr ⁻¹ spruce 1.0 yr ⁻¹ broadleaved	Tatarinov and Cienciala (2006)
CENTURY	User defined, single value for site at any given time, can be different between grasses and trees	0.9 yr ⁻¹ lodgepole pine	Parton et al. (1987); Smithwick et al. (2009)
CLM-CN	Defined as one of two possible rates depending on PFT	0.5 yr ⁻¹ or 1.0 yr ⁻¹	Levis et al. (2004)
ED2	User defined, can have different values for different species or PFTs	0.33 yr ⁻¹ , optimized range up to 6.6 yr ^{-1a}	Medvigy et al. (2009); Kim et al. (2012)
Fire-BGC	Set equal to leaf turnover	1.0 yr ⁻¹ for leaves and fine roots	Keane et al. (2011)
FORCENT	User defined. Contains two separate pools of fine roots of faster and slower turnover times	Maximum rate of 2.2–9.6 yr ⁻¹	Parton et al. (2010)
IBIS	Fixed across all PFTs	1.0 yr ⁻¹	Kucharik et al. (2006)
JULES	Defined as one of two possible rates depending on PFT	0.15 yr ⁻¹ or 0.25 yr ⁻¹	Clark et al. (2011)
LANDCARB	Maximum turnover rate is user defined by species. Absolute rate varies with light absorbed by canopy.	0.5 yr ⁻¹	Harmon et al. (2009); Sierra et al. (2009)
LANDIS-II	Can be defined by species. May also temporarily increase to reflect losses in aboveground biomass.	0.6 or 1.0 yr ⁻¹	Dymond et al. (2012)
LM3V	Defined for different PFTs	1.0 yr ⁻¹ for temperate deciduous and 0.6 yr ⁻¹ for cold evergreen trees	Shevliakova et al. (2009)
LPJ	Defined as one of two possible rates depending on PFT	0.5 yr ⁻¹ or 1.0 yr ⁻¹	Sitch et al. (2003)
MC1	User defined, can have different values for different PFTs	1.1 yr ⁻¹ for deciduous broadleaf 1.3 yr ⁻¹ for evergreen needleleaf 0.86 yr ⁻¹	Bachelet et al. (2000); Daly et al. (2000); Rogers et al. (2011)
Orchidee	User defined, can have different values for different PFTs	0.86 yr ⁻¹	Ciais et al. (2008)
PnET-CN	Varies as a function of annual nitrogen mineralization	Typical range of 0.48–0.82 yr ⁻¹	Aber et al. (1997); Ollinger et al. (2002)
PPA	User defined	0.3 yr ⁻¹ , 0.7 yr ⁻¹	(Fisher et al., 2010); Dybzinski et al. (2011)
SiBCASA	Fixed across all PFTs	1.0 yr ⁻¹	Schaefer et al. (2008)
TRIFFID	Set equal to minimum leaf turnover rate	0.25 yr ⁻¹	Cox (2001)

^a Fine root turnover rate in ED2 incorporates production of short-lived root exudates.

Download English Version:

<https://daneshyari.com/en/article/4375821>

Download Persian Version:

<https://daneshyari.com/article/4375821>

[Daneshyari.com](https://daneshyari.com)