Model of Fine Root Lifespans Using A Locally-Released Radiocarbon Label

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Background

Fine roots (< 2 mm diameter) are dynamic and a large pump of carbon belowground.

Big unknown in terrestrial C cycling, and for EBIS
Belowground C input and its residence time in soil.
How much C is **transferred** belowground by root growth?

Estimates of Fine Root Lifespans by Different Methods

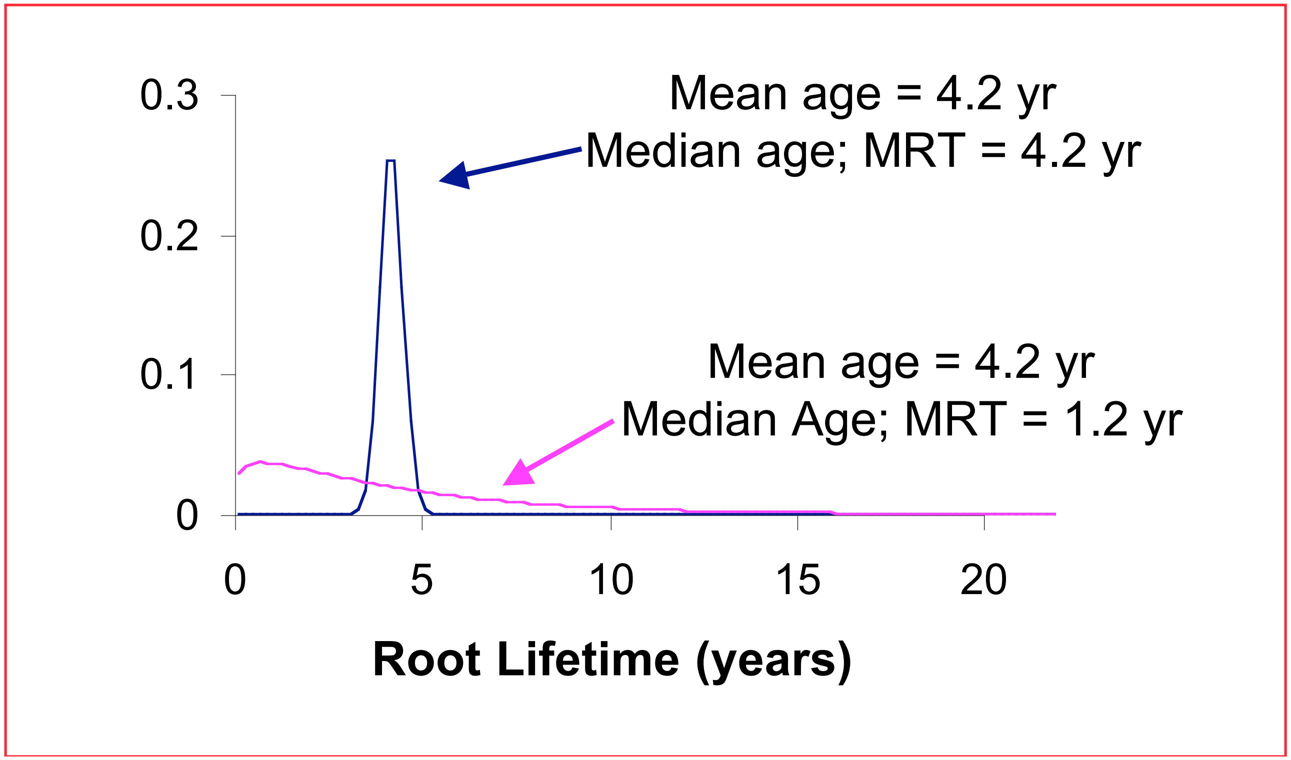
Pre-1990's: Coring and nutrient budget techniques	**1 < 3 years**
Early-1990's: Minirhizotron technique	**< 1 year**
Early-2000's: Isotopic techniques (^{13}C and ^{14}C)	**3-10+ years**

Modeling

Part of the problem: past assumptions

- **Single Pool with one turnover time**
  Turnover time (y) = stock/production

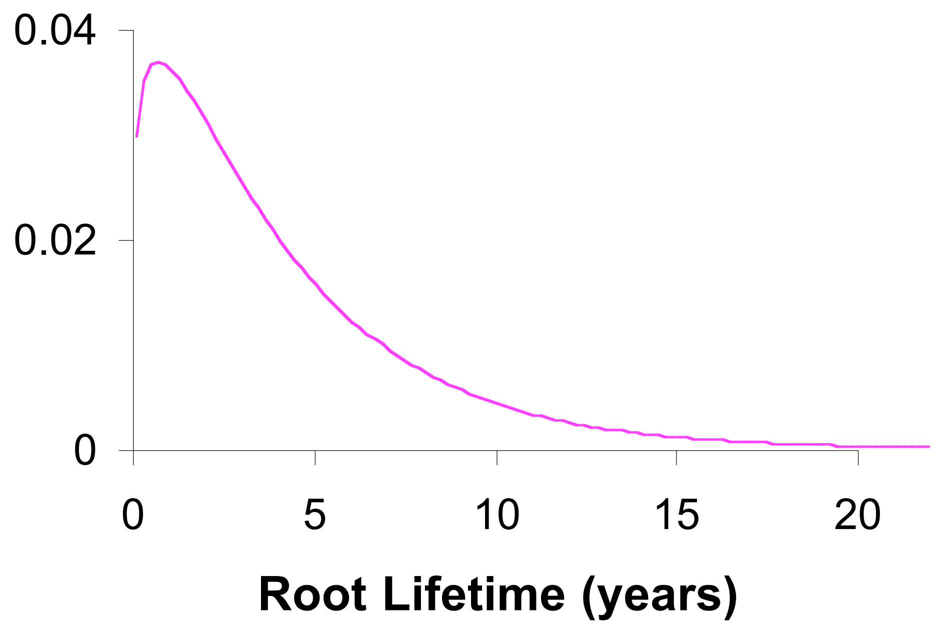
- **Age of population is symmetrically distributed**
  Probability of death is equal



Modeling

Part of the solution:

Incorporate that fine roots have large variation in lifespans, by using right-skewed populations and multiple pools.



Adapted from Trumbore and Gaudinski 2003

Supported by Tierney and Fahey 2002.

Modeling Goals

1. **Allow for root ages that are non-normally distributed**
    1. we use a right skew, lognormal distribution
2. **Represent fine roots as two pools**

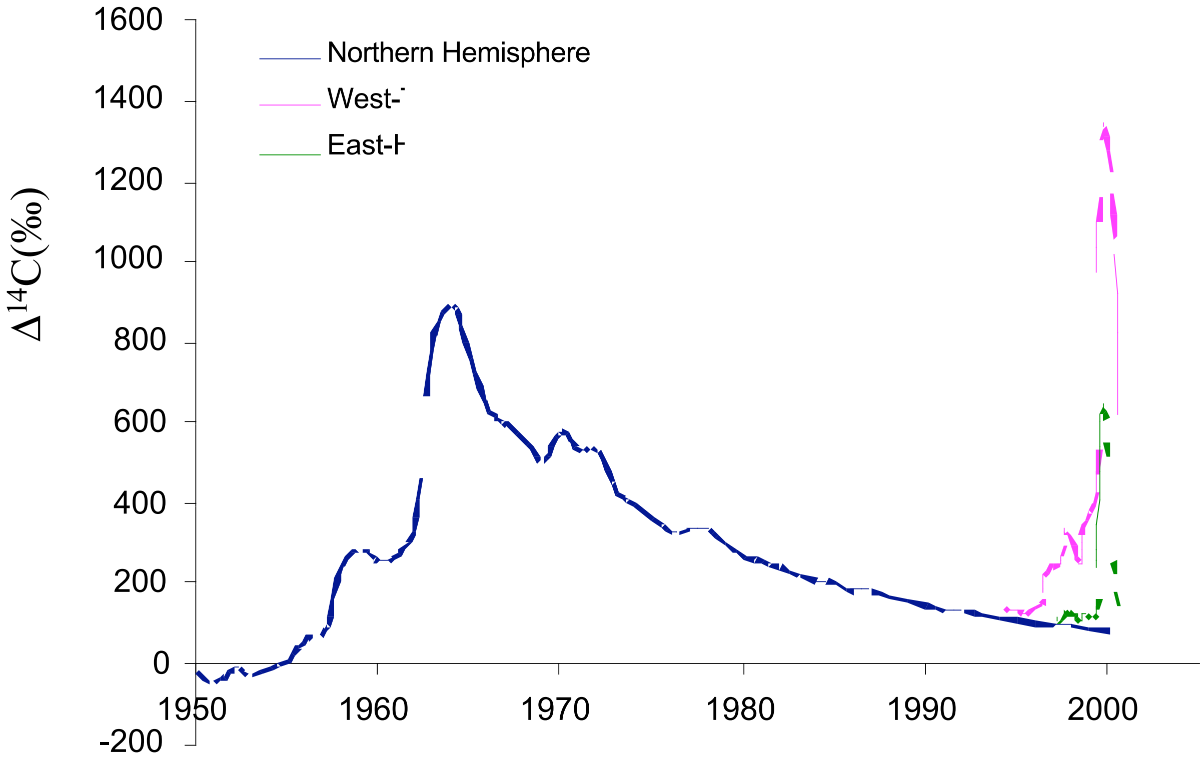
    short- & long-lived
3. **Account for influence of stored C/^{14}C**
4. **Estimate How Much & Res Time for growth from stored C**
5. **Represent both structural and non-structural C.**

    soxhlet extraction for cellulose and non-cellulose C

Other Attributes

- Include seasonal growth patterns.
- Include Monte Carlo analysis of uncertainty.

EBIS: Oak Ridge Tennessee



Oak Ridge, TN

Mixed Deciduous Forest

Use EBIS data for modeling

Local ^{14}C release: sensitive signal to constrain a ^{14}C model

1. **Characterize the contribution of stored C to root growth**
2. **Parameterize a multi-pool model**

Need “EBIS project” atmos $^{14}CO_2$ record

Data Qualities

Timing, location, interpretation, integration

Data sources

Soil Respiration

Soil Gas

Atmosphere Flasks -- instantaneous

Atmosphere Flasks -- cumulative

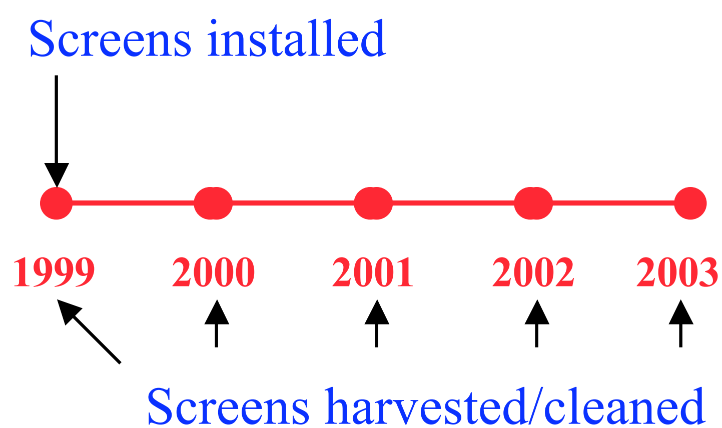
Leaves

Fungi ?

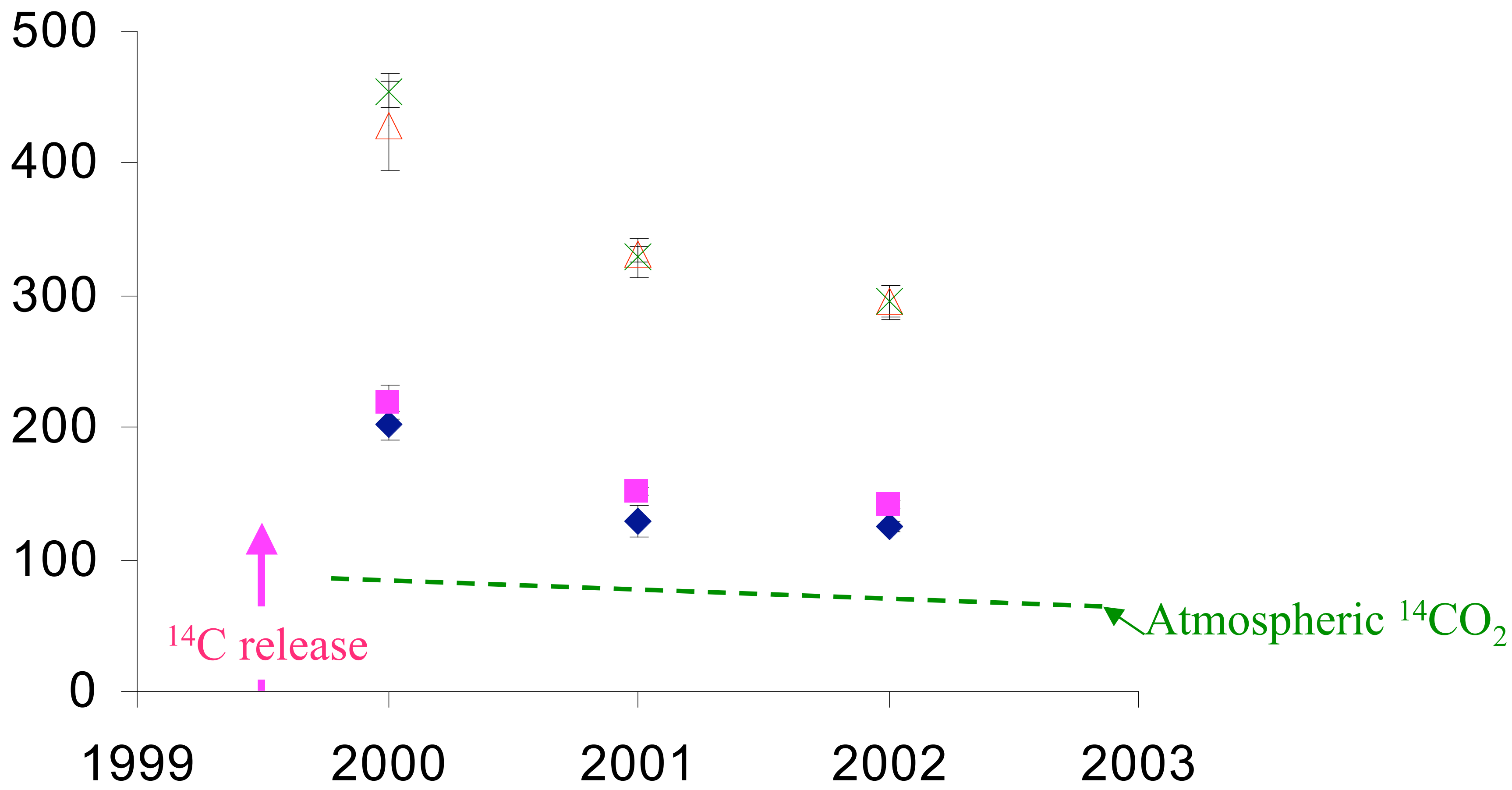
Tree Cores: Wood Cellulose

1. Root Screens → Influence of Storage

- Isotopic techniques account for age since C fixation.
- Time spent as stored C adds to apparent age
- Previous Bomb-^{14}C research showed storage < 2 years
- Storage affects age even for reserves < 6 months (Luo 2003)

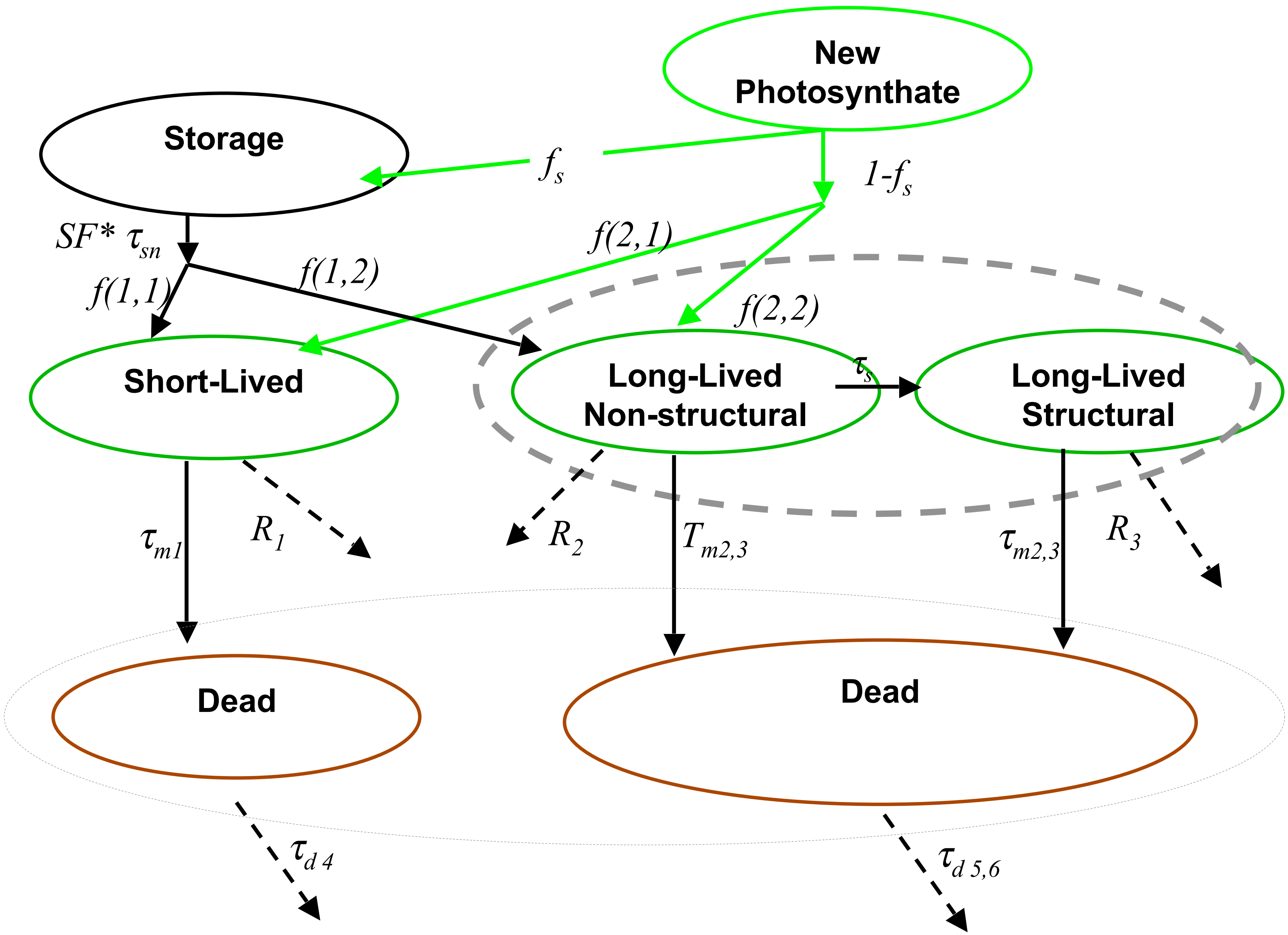


2. Root Cores → Model Structure



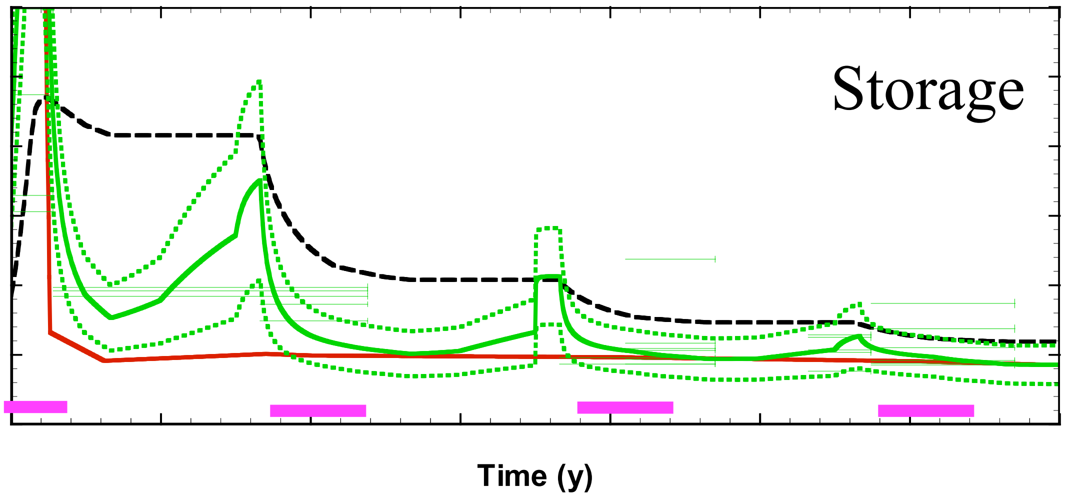
- Rapid increase of live & dead ^{14}C requires "fast" cycling live pool.
- Persistant elevation of ^{14}C requires "slow" cycling pool.

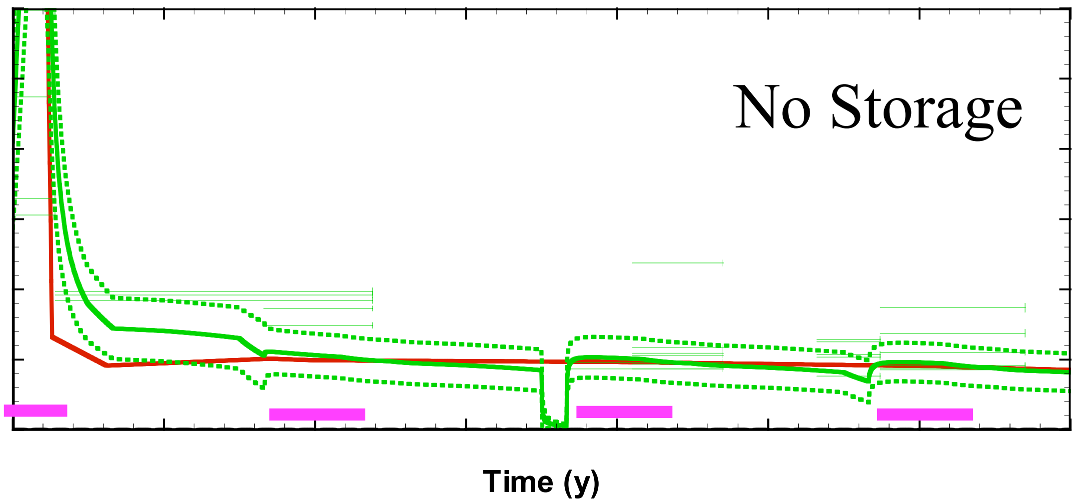
Root Model


New Photosynthate
Storage
f_s
$1-f_s$
$SF^* \tau_{sn}$
$f(1,1)$
$f(1,2)$
$f(2,1)$
$f(2,2)$
Short-Lived
Long-Lived Non-structural
τ_s
Long-Lived Structural
τ_{m1}
R_1
R_2
$T_{m2,3}$
$\tau_{m2,3}$
R_3
Dead
Dead
$\tau_{d\,4}$
$\tau_{d\,5,6}$

Model Results-Storage

Predicted fast pool ^{14}C and measured root screen ^{14}C





Storage helps model fit the data, especially right after release

Storage makes up 10% of annual new growth (both pools).

Age of stored C ~ 1.3 years.

Model Results-Turnover Times

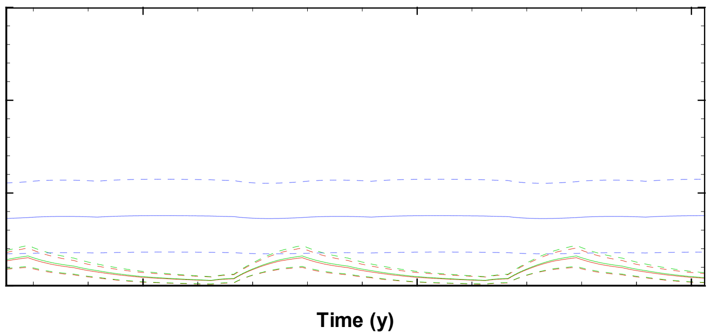
Predicted ^{14}C (root population) vs. Measured ^{14}C(cores)

East Side

West Side

Live

Dead

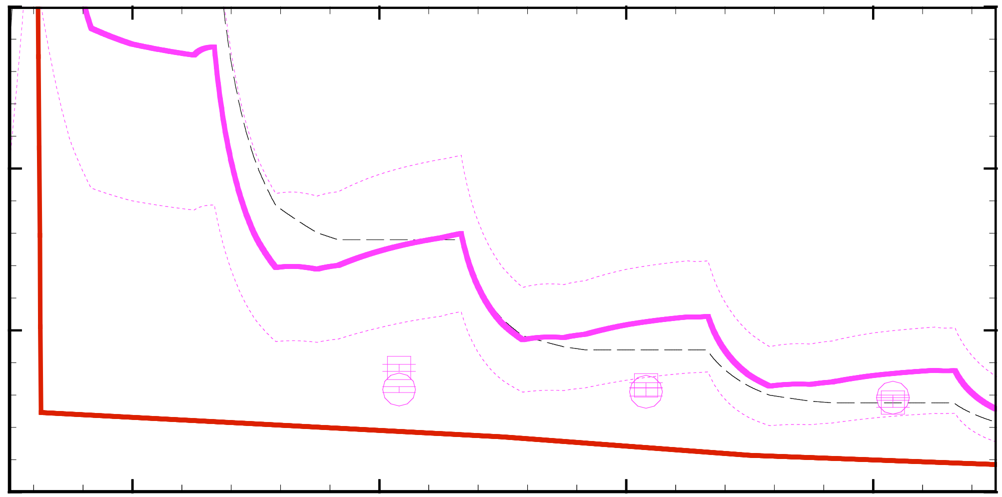


Live root τ:'s = 6 mos. & 5 yrs.

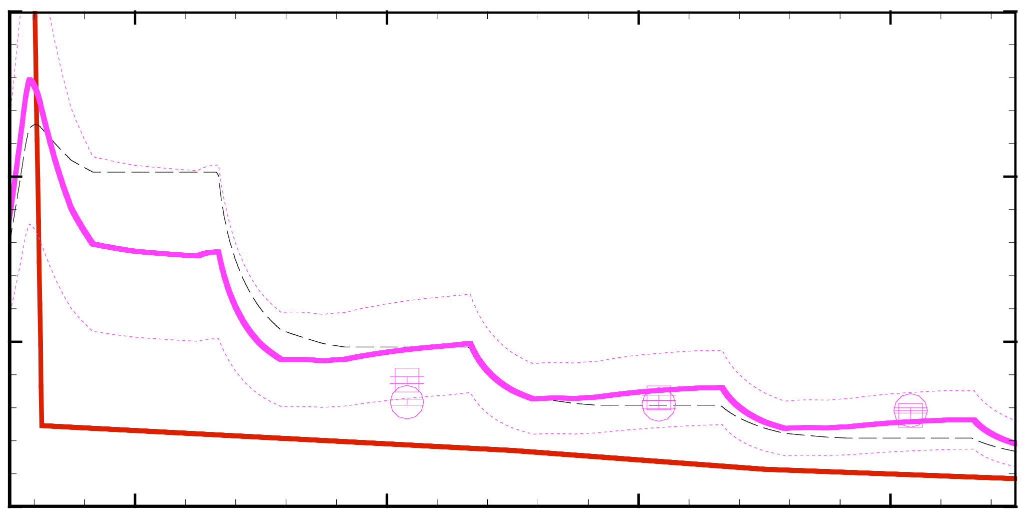
Dead roots τ:'s = 6 mos. & 7 yrs.

Model Results—Effect of Atm Values
TVA with Different Peak Inputs, Live Roots

6400 ‰



3000 ‰



Flux of Fine Root C/^{14}C
0-15 cm

Method

Flux = stock/τ

East side results

	Year	Non-Str C	Dead roots
^{14}C (‰)	1999		
	2000	**954**	**250**
	2001	**556**	**328**
	2002	**214**	**322**
	2003	**140**	**305**
		96	**286**
Flux ($g\ m^{-2}\ y^{-1}$)	all	0.3	21

Conclusions

Model Structure, important complexities in fine root dynamics:

- **Two pools**
- **Storage**
- **Non-symmetric probabilities of death or decay.**

Preliminary Model Results:

- **~10% of new root growth is from storage**
- **Age of storage pool is 1.3 years.**
- **Lifespans for live roots → 6 mos. and 5 years**
- **Dead root decomposition rates → 6 mos. and 7 years**

Future directions:

- **Inversion modeling and chi squared fit analysis.**
- **Sensitivity analysis (f_s, tau's, R-atm)**
- **Need better estimate of original ^{14}C inputs**
- **Useful to have better way to pro-rate BGPP rather than by biomass**

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