The role of harvest residue in rotation cycle carbon balance in loblolly pine plantations

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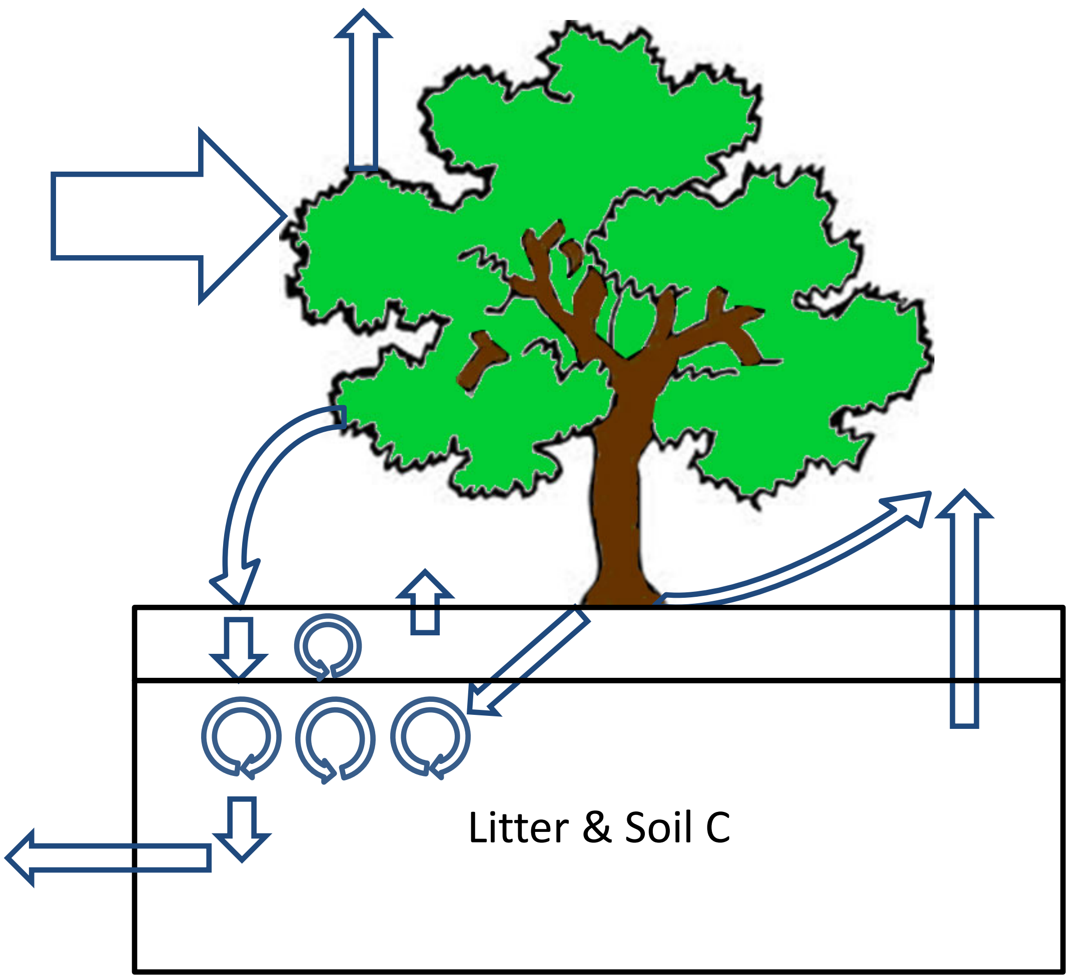
Outline

- The problem: reconciling commercial production and carbon sequestration
- Loblolly pine as the model system
  - Ecosystem carbon balance vs. soil carbon balance
- Results
  - Soil C balance
  - Harvest residue dynamics
  - Partitioning respiration

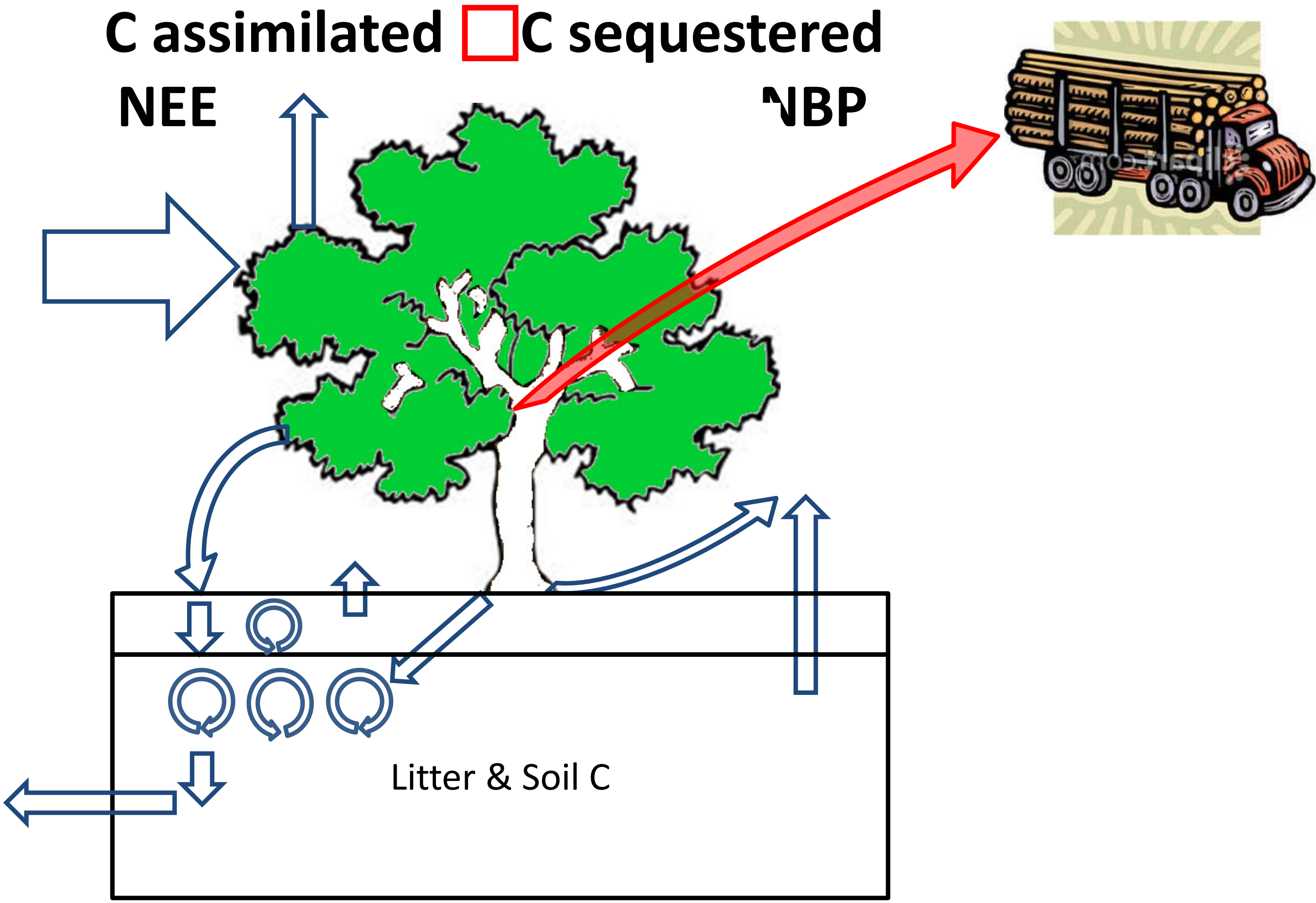
Noormets et al. (2010) Response of carbon fluxes to drought in a coastal plain loblolly pine forest. *Global Change Biology* 16: 272-287

Noormets et al. (2012) The role of harvest residue in rotation cycle carbon balance in loblolly pine plantations. Respiration partitioning approach. *Global Change Biology* 18: 3186–3201

Ecosystem C cycle



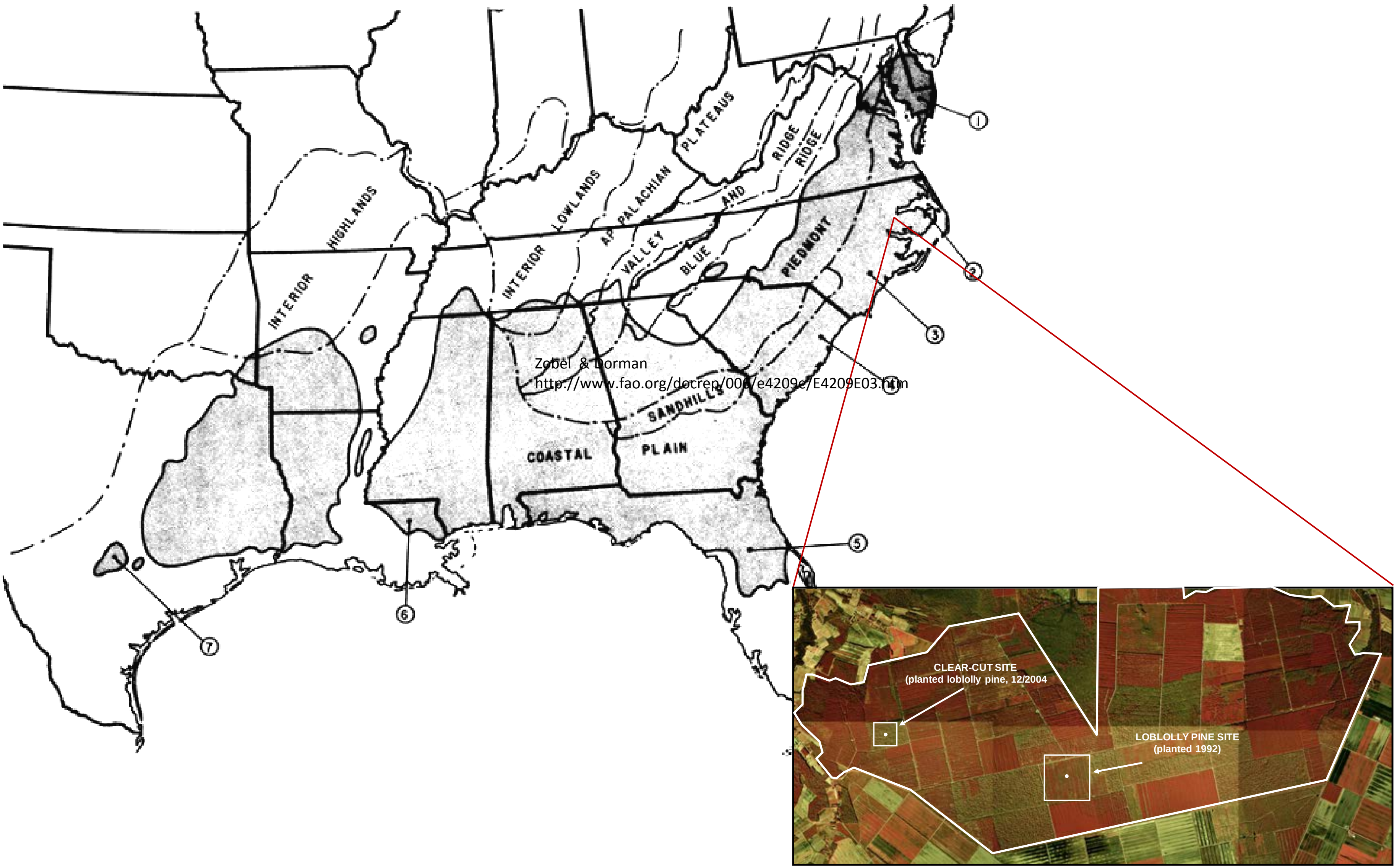
Plantation is an open system



Why does it matter?

- Effect on C sequestration
- Stoichiometric effects
- Episodic removal, must consider entire forest life cycle

Study area



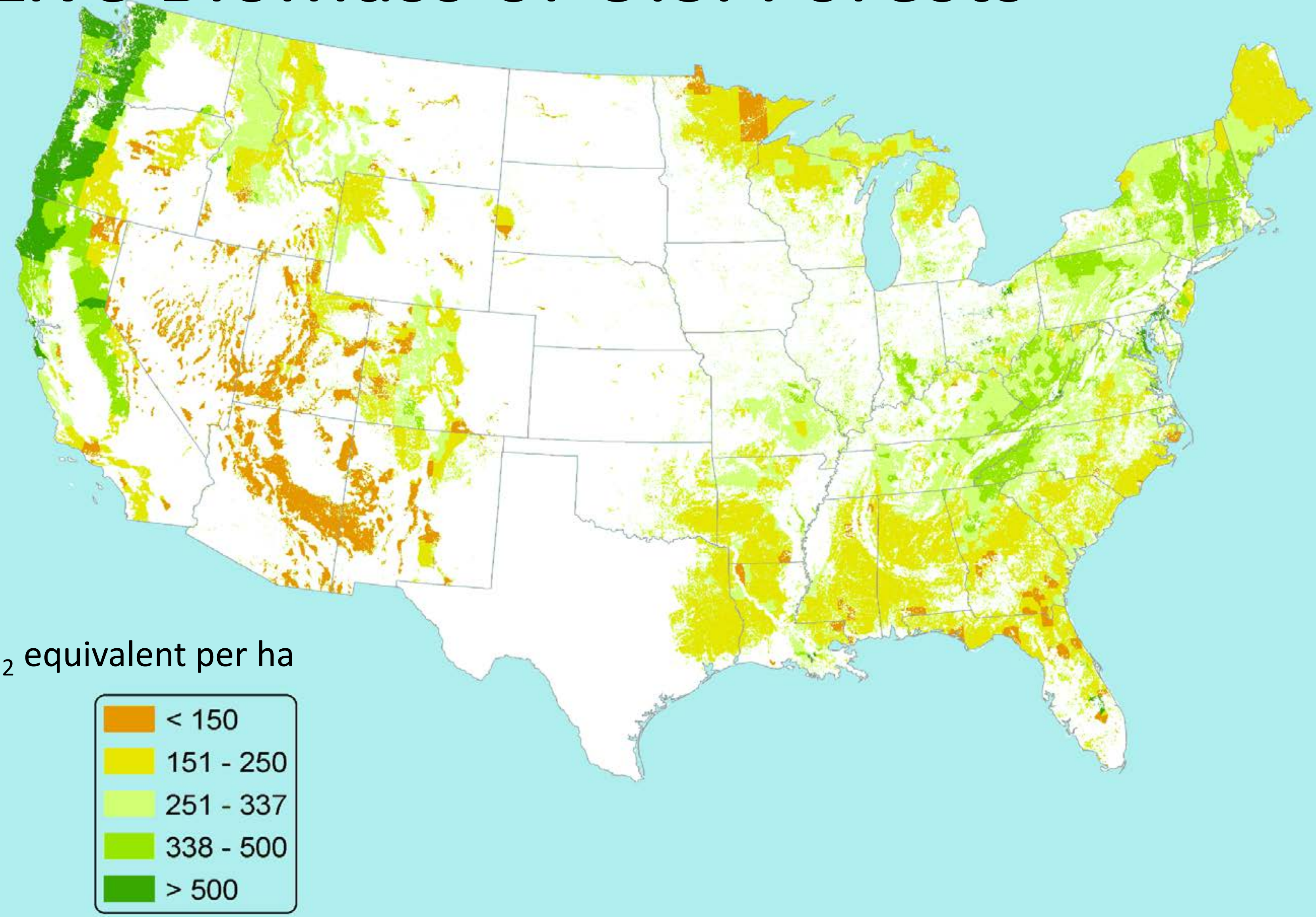
Zobel & Dorman
http://www.fao.org/docrep/006/e4209e/E4209E03.htm

Loblolly pine & plantation forests

- Produce 16% of global industrial wood, more than any other country
- Over 80% of new plantations in loblolly pine
- 55% of loblolly pine in USA is in plantations

- Contain 36% of the C sequestered in the contiguous USA (12 Pg)
- Sequester 13% of regional GHG emissions (76 Tg)

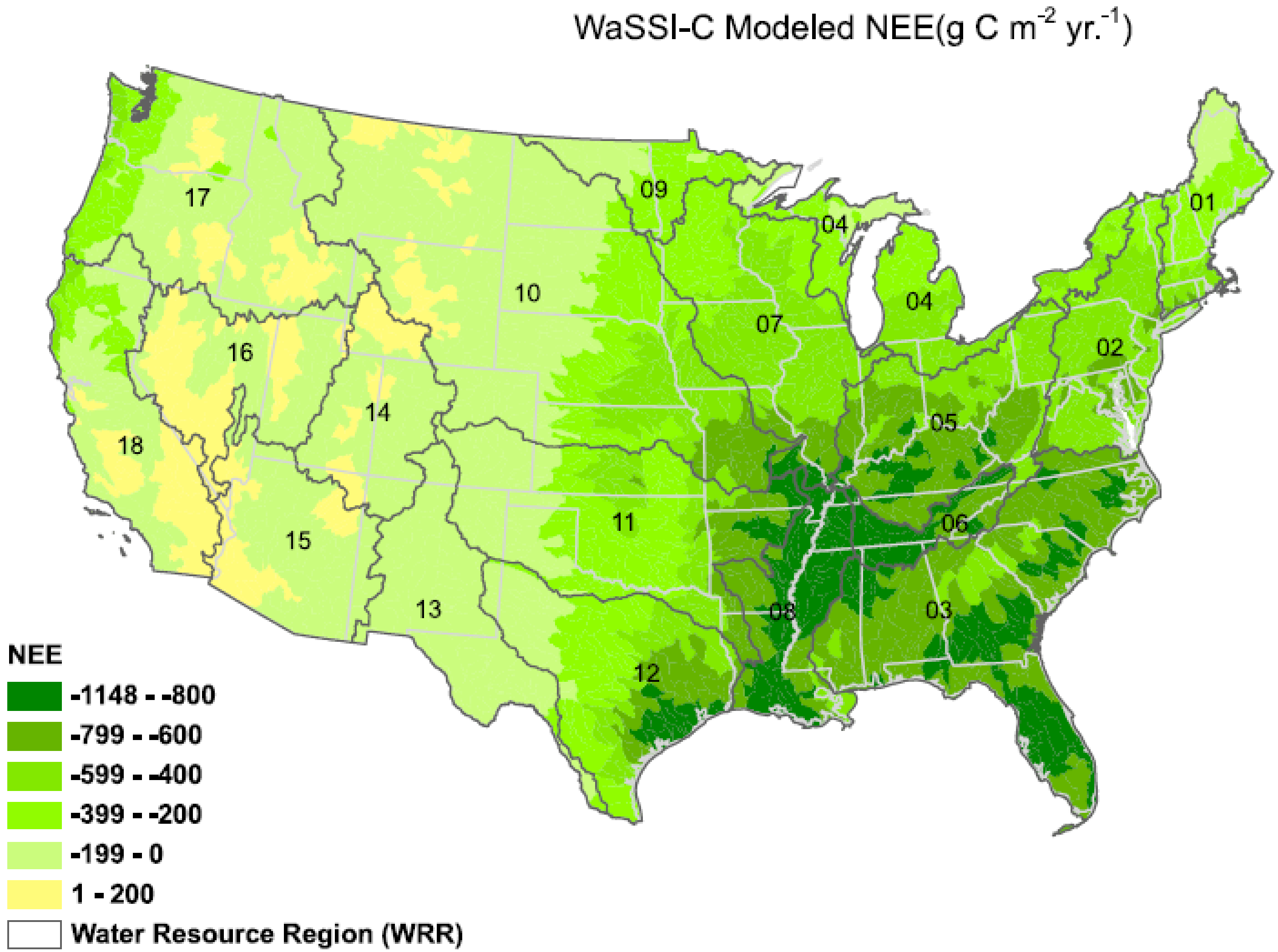
Live Biomass of U.S. Forests



Mg CO_2 equivalent per ha

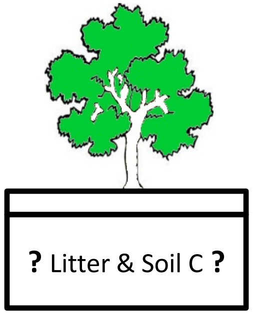
Source: Linda Heath, USDA FS

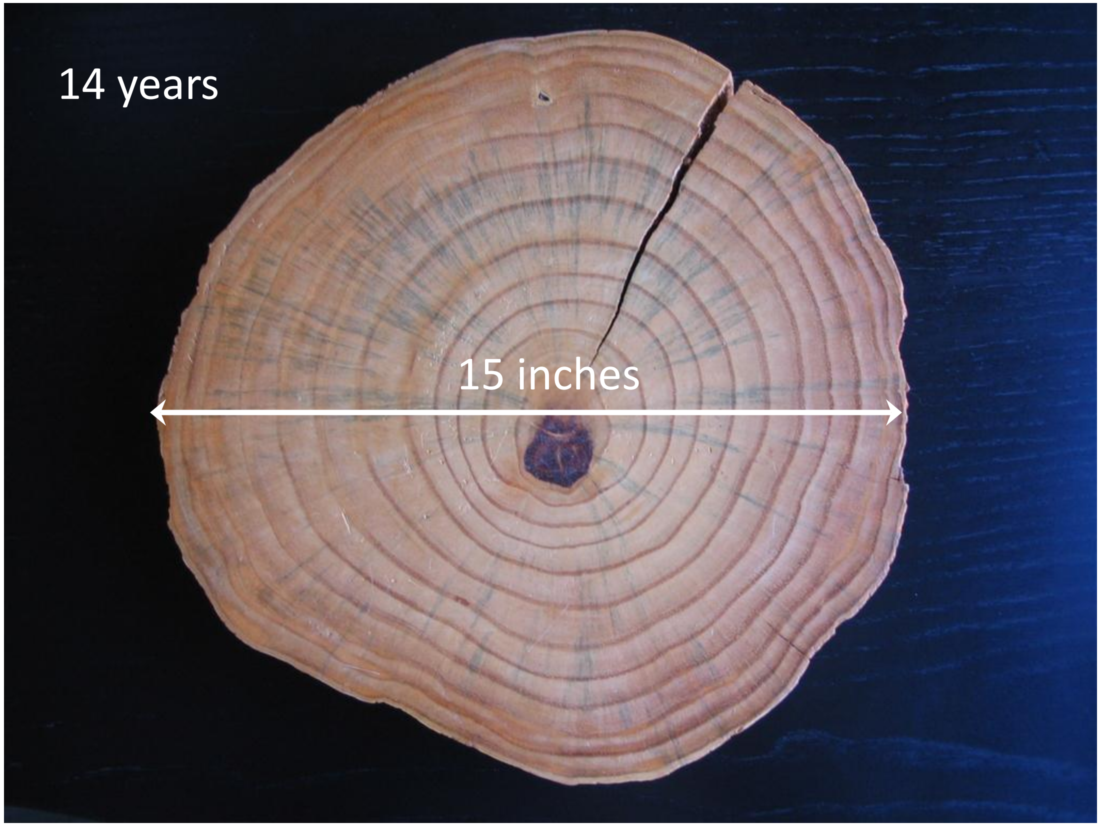
Annual NEE of natural ecosystems



Sun et al., 2011, JGR

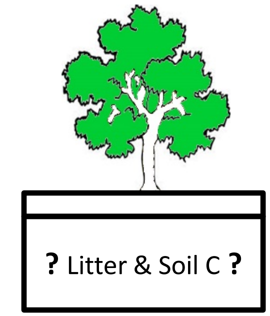
High productivity





NEP: 700±238 g C m^{-2} yr^{-1}

Soil C balance



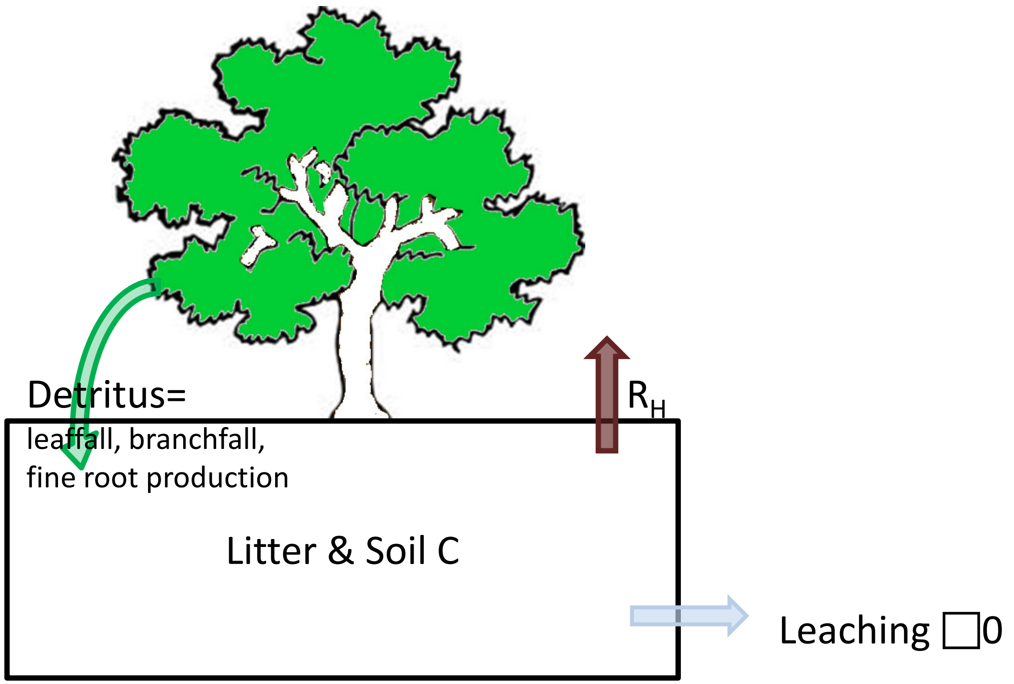
How much residue gets sequestered in the long term?

How does contribution from above- and below-ground components differ?

Does R_H increase?

Does the pulse of harvest residue trigger an increase disproportionate to its size, i.e. is there priming?

Soil C balance = inputs-outputs



1. Belowground allocation vs. heterotrophic respiration (BGA:R_H)
2. Decay of harvest residue
3. Partitioning of respiration

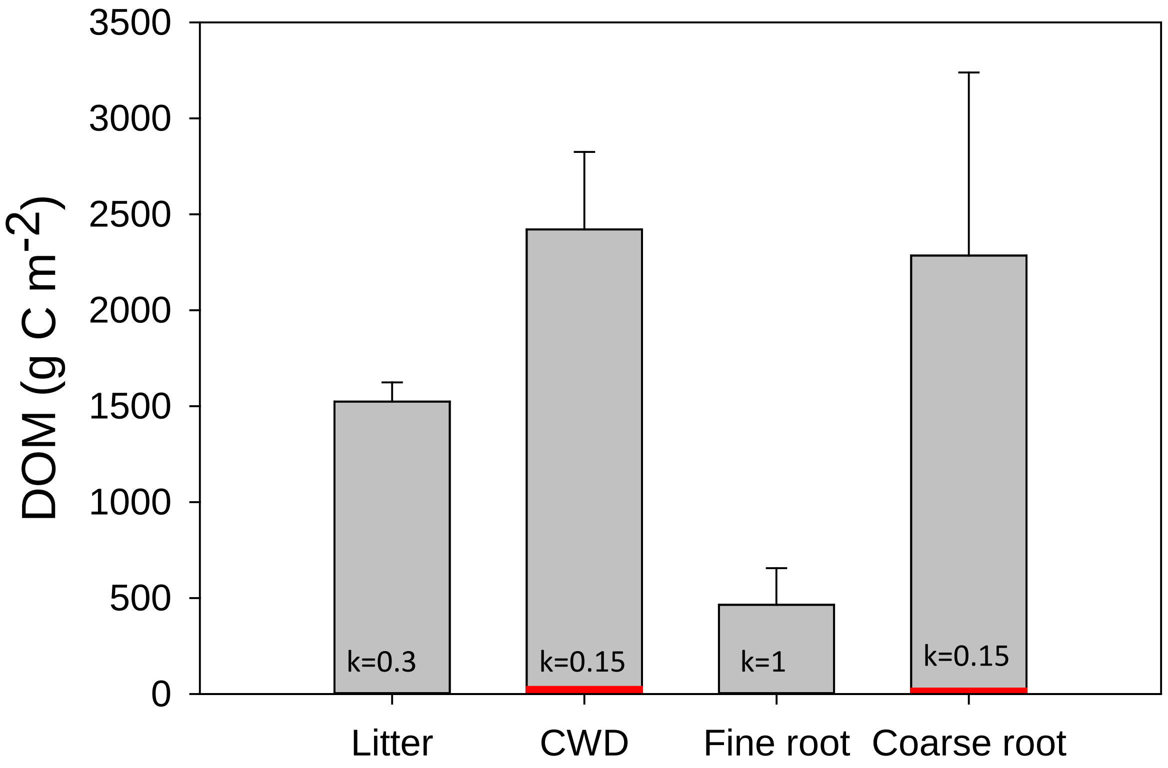
1. Detritus:R_H

Age 13-17	2005	2006	2007	2008	2009	Total
Detritus	420	530	520	560	440	2470
R_H = **0.5** × SR	665	558	570	598	550	2941
Detritus:$R_{H0.5}$	0.63	0.95	0.91	0.94	0.80	**0.84**
R_H (**BL2004**)	646	568	578	570	562	2924
Detritus:R_{HBL}	0.65	0.93	0.90	0.98	0.78	**0.84**

Average deficit (years 13-17): 93 g C m^{-2} yr^{-1}

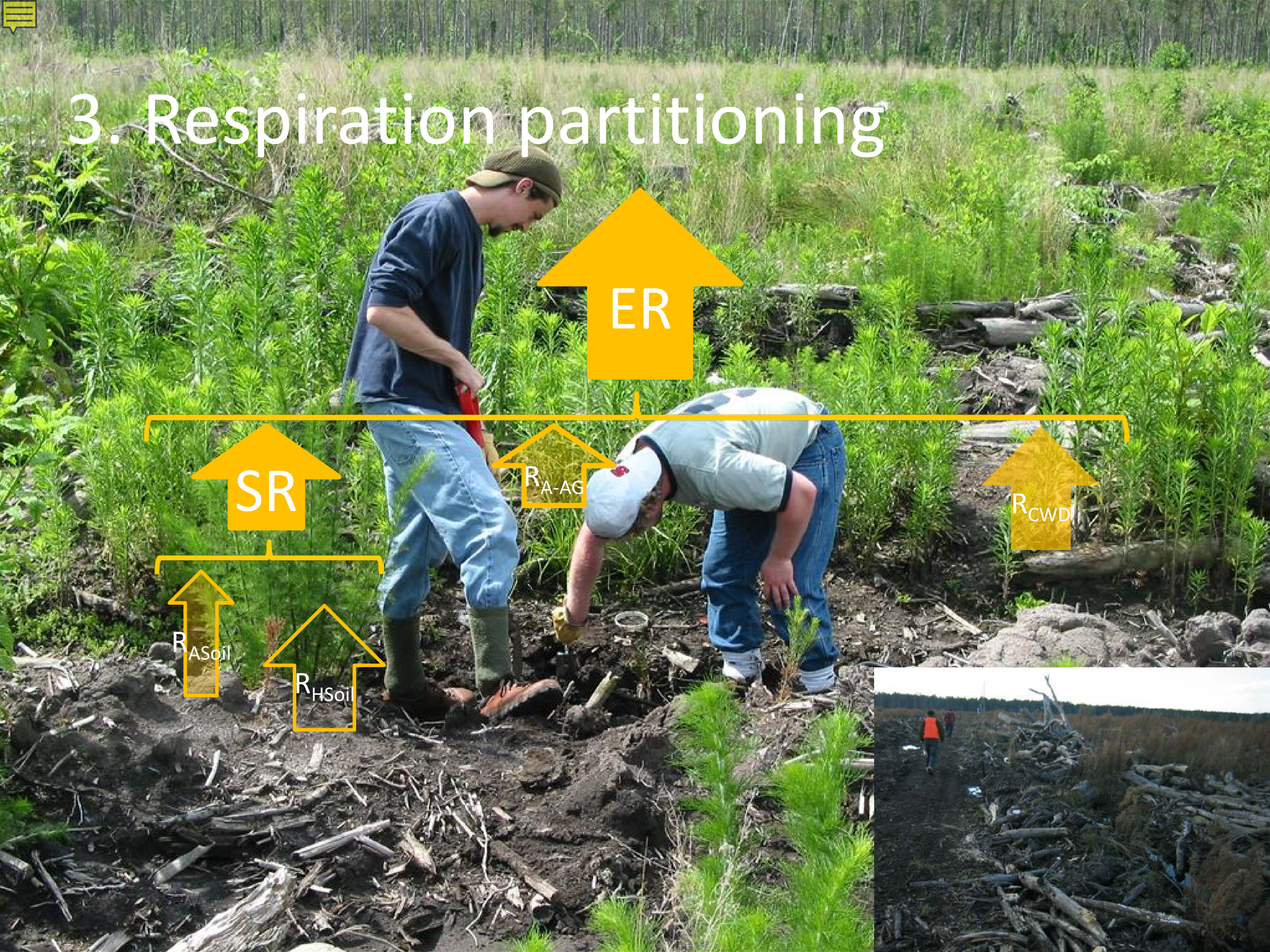
Noormets *et al.*, 2010, *GCB*

2. Harvest residue input

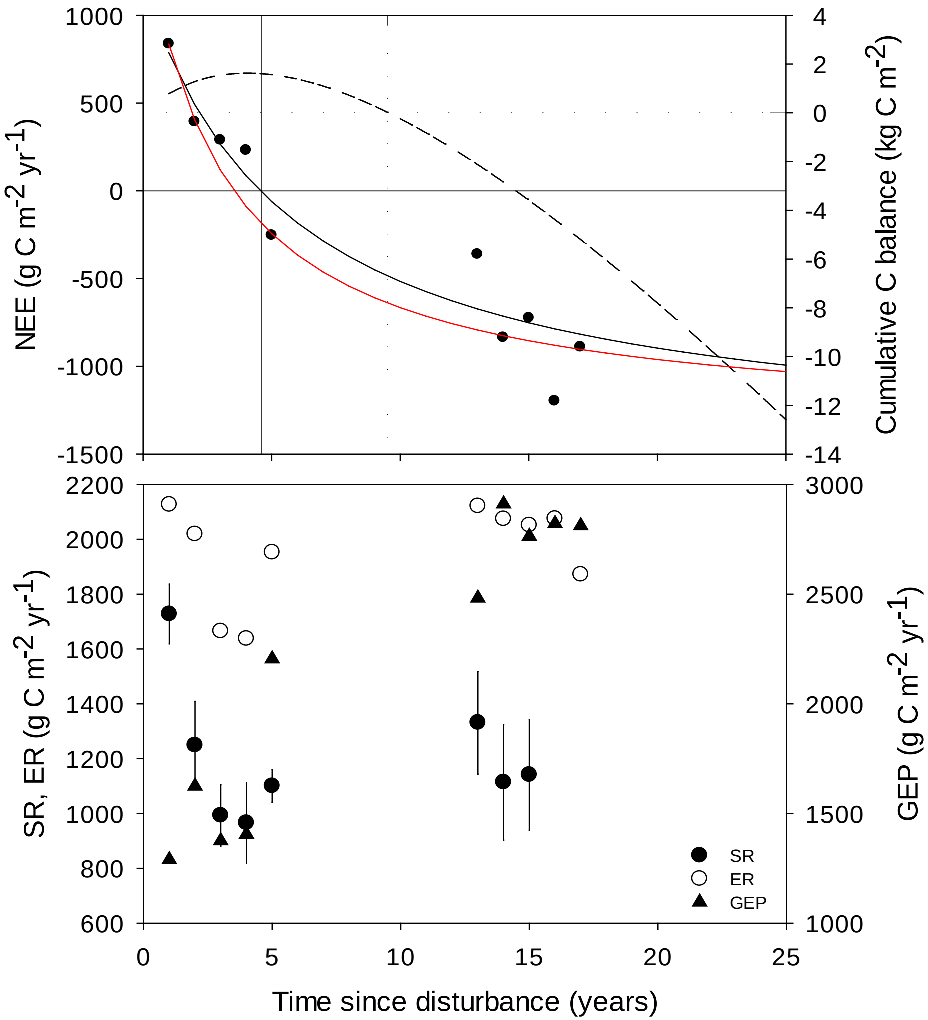


$$DOM_{25} = DOM_0 e^{-kt} = 93 - 138\ g\ C\ m^{-2}$$

3. Respiration partitioning

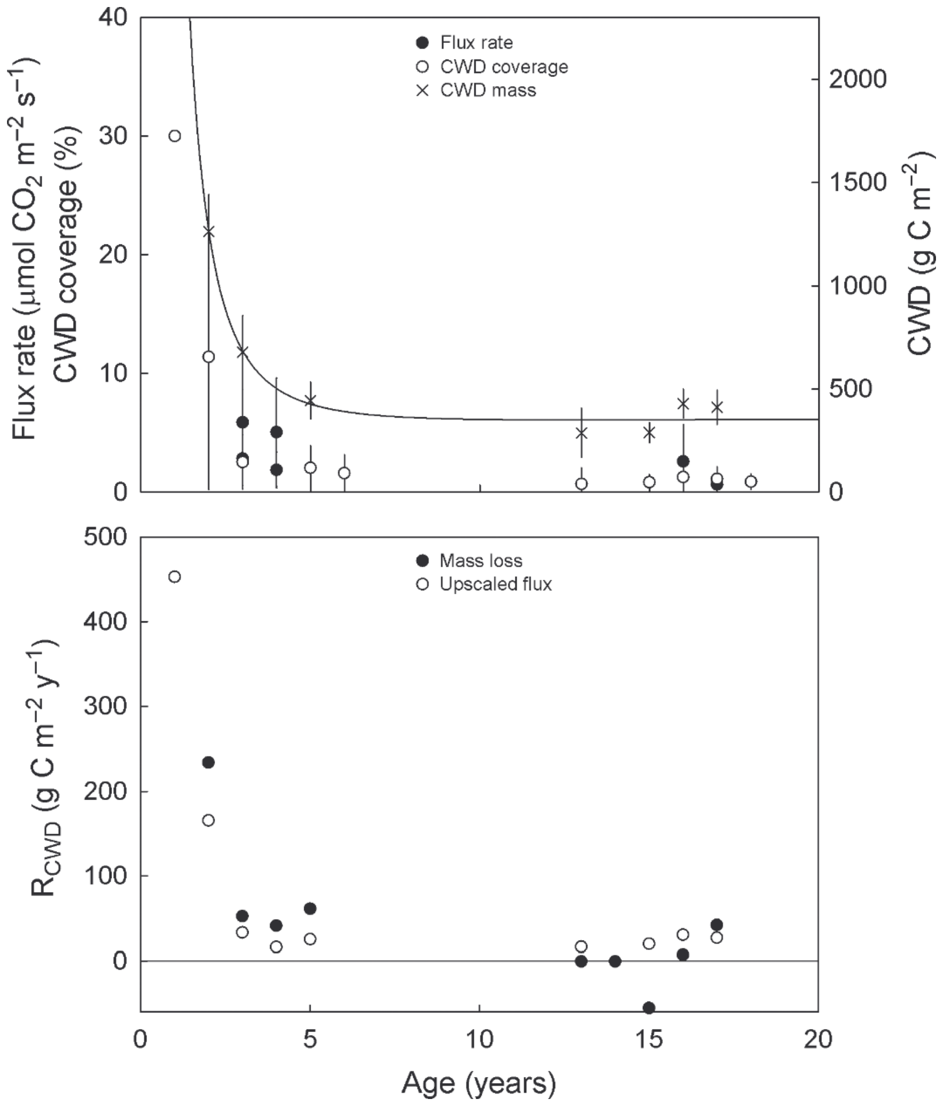


Age-related changes in C exchange



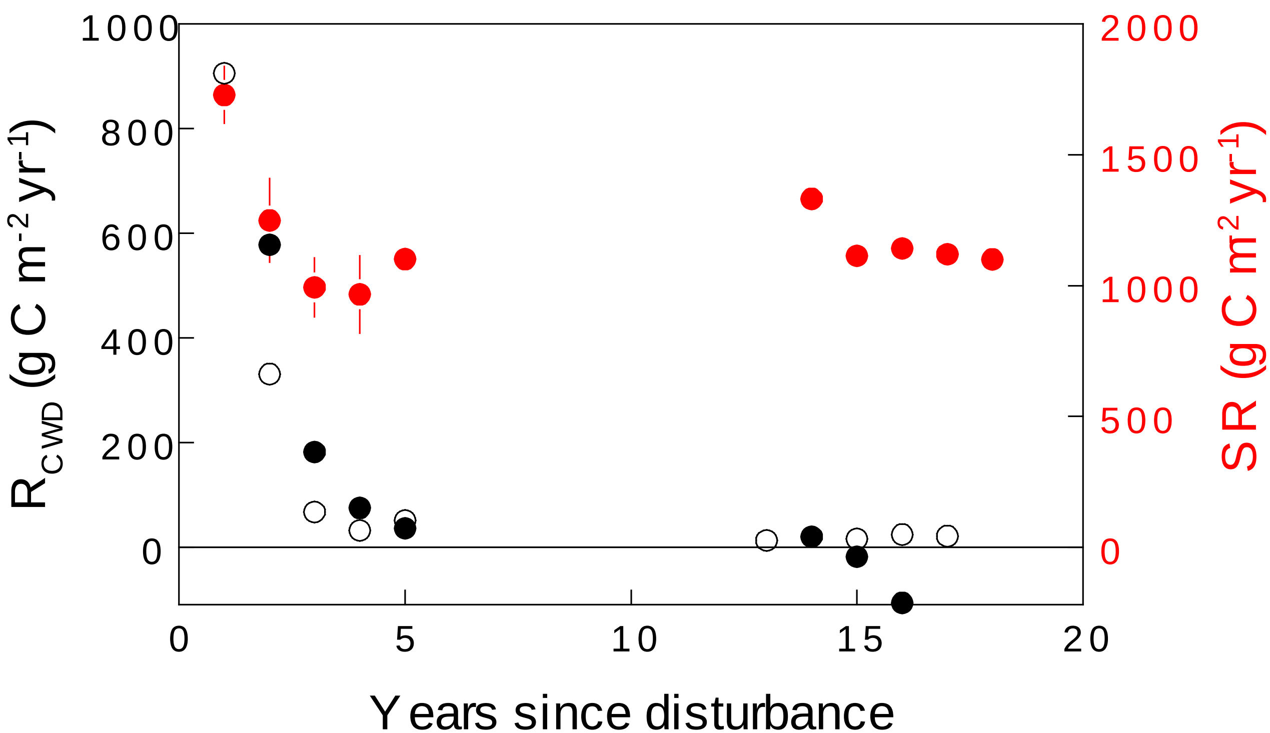
Noormets et al., 2012, GCB

Coarse woody debris decomposition



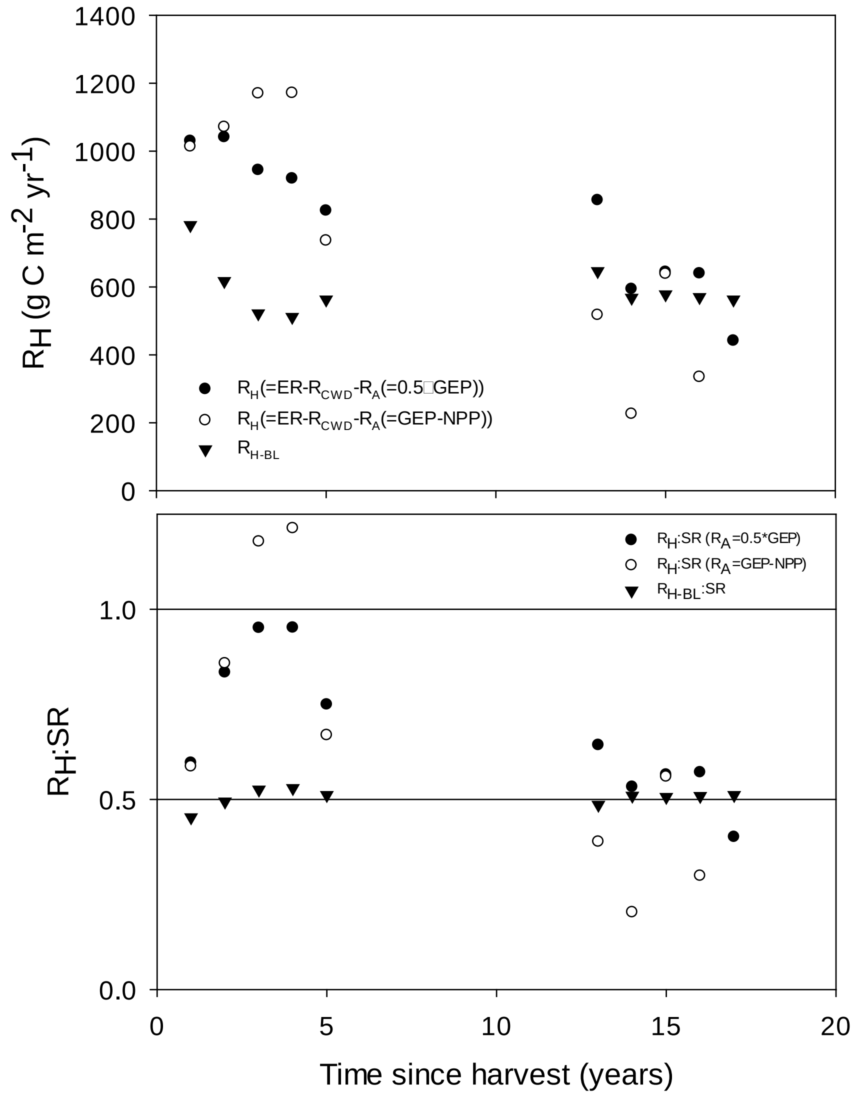
Noormets et al., 2012, GCB

Respiration dynamics, R_{CWD} & SR



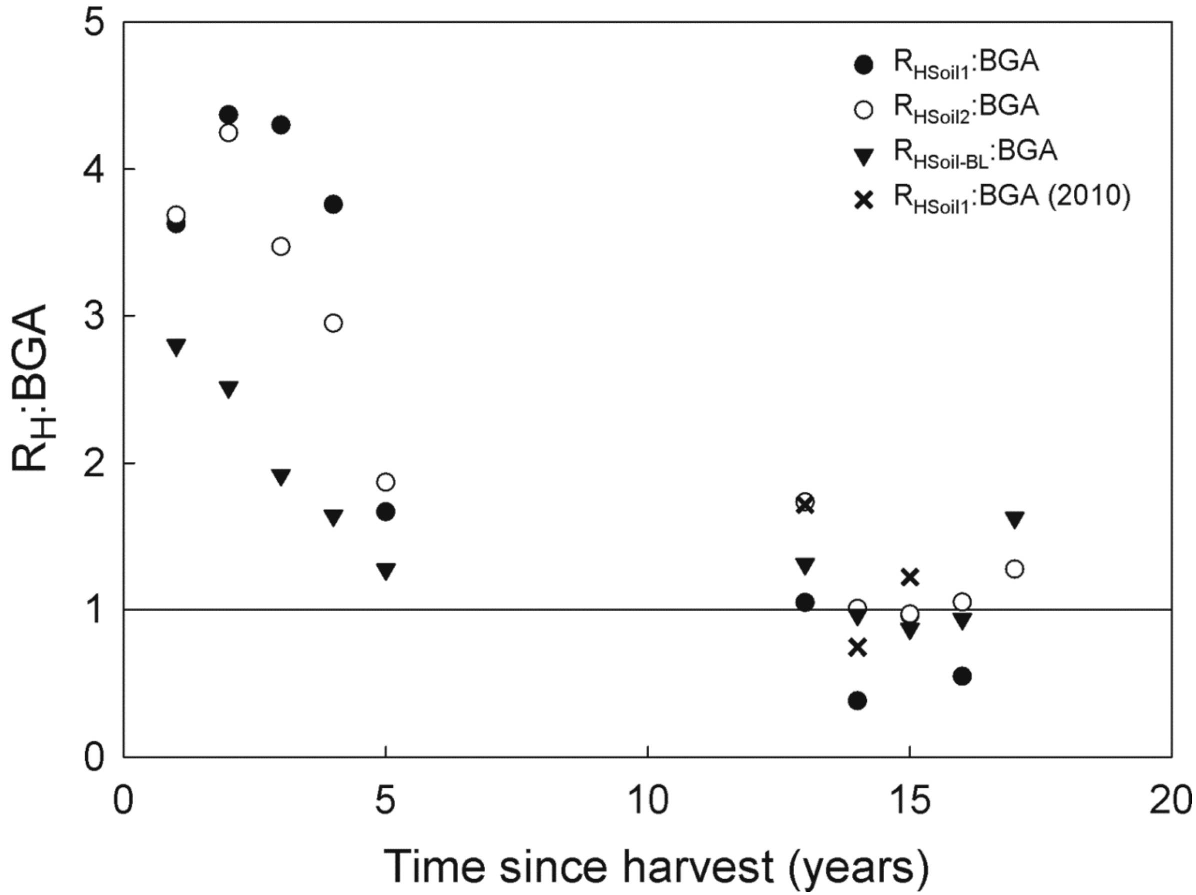
Noormets et al., 2012, GCB

Soil heterotrophic respiration



Noormets et al., 2012, GCB

Soil carbon deficit



Soil C deficit: $\sum_{1}^{25}(Detritus - R_H) = -124 \ldots - 267 g\ C\ m^{-2} yr^{-1}$

Noormets *et al.*, 2010, 2012, *GCB*

Dead organic matter dynamics (1)

$$DOM_{AG\,t} = DOM_{AG\,t-1} - ER_{AG\,t} f^{ER}_{AG\,t} - SR_t f^{SR}_{AG\,t} + P_{CWD\,t} + P_{Branch\,t}$$

$$DOM_{BG\,t} = DOM_{BG\,t-1} - SR_t f^{SR}_{BG\,t} + P_{Litter\,t} + P_{FineRoot\,t} + P_{DeadCoarseRoot\,t}$$

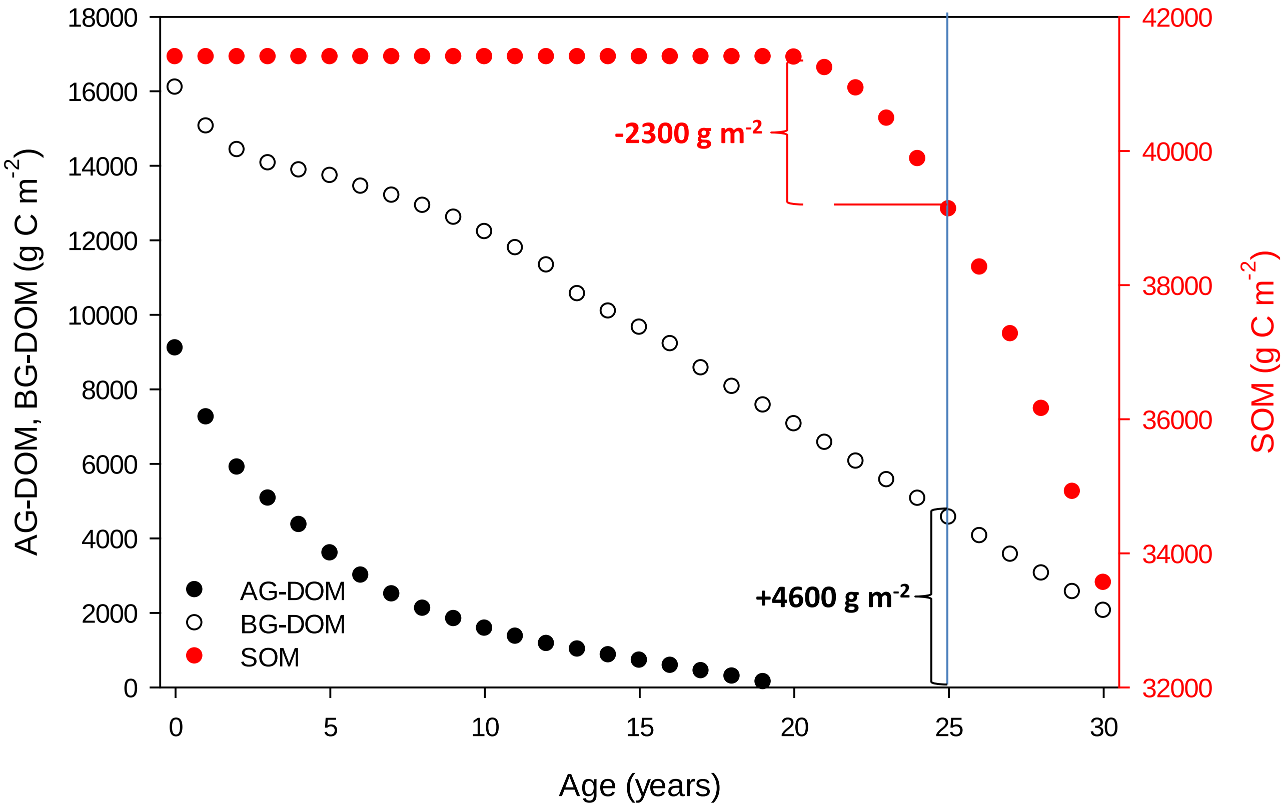
DOM_{AGt}, DOM_{BGt} – above- & belowground DOM pools in year t

ER_t, SR_t – ecosystem and soil respiration rates in year t

P_{CWD}, P_{Branch}, P_{Litter}, $P_{FineRoot}$, $P_{DeadCoarseRoot}$ – annual production rates of given DOM pools

f^{SR}_{AGt}, f^{SR}_{BGt} – fraction of above- and belowground DOM contributing to SR in year t ($f^{SR}_{AGt} + f^{SR}_{BGt} = 1$). Estimated. Same for f^{ER}_{AGt}.

Dead organic matter dynamics (2)



$$\frac{dDOM_{BG} - dSOM}{25} = 80 - 100\ g\ C\ m^{-2} yr^{-1}$$

Summary

- Running soil C deficit: 124-267 g C m^{-2} yr^{-1}
- Harvest residue surplus: 80-100 g C m^{-2} yr^{-1}

- Long-term C sequestration potential ≤ 0

- Modified management may help reduce soil C losses while optimizing productivity
- This work can inform policy decisions for forest management

Remaining measurement uncertainties

- Amount of residue ploughed into soil
- Rate of decomposition at later stages of decay
- Rate of fragmentation
- Area-wide coverage of CWD

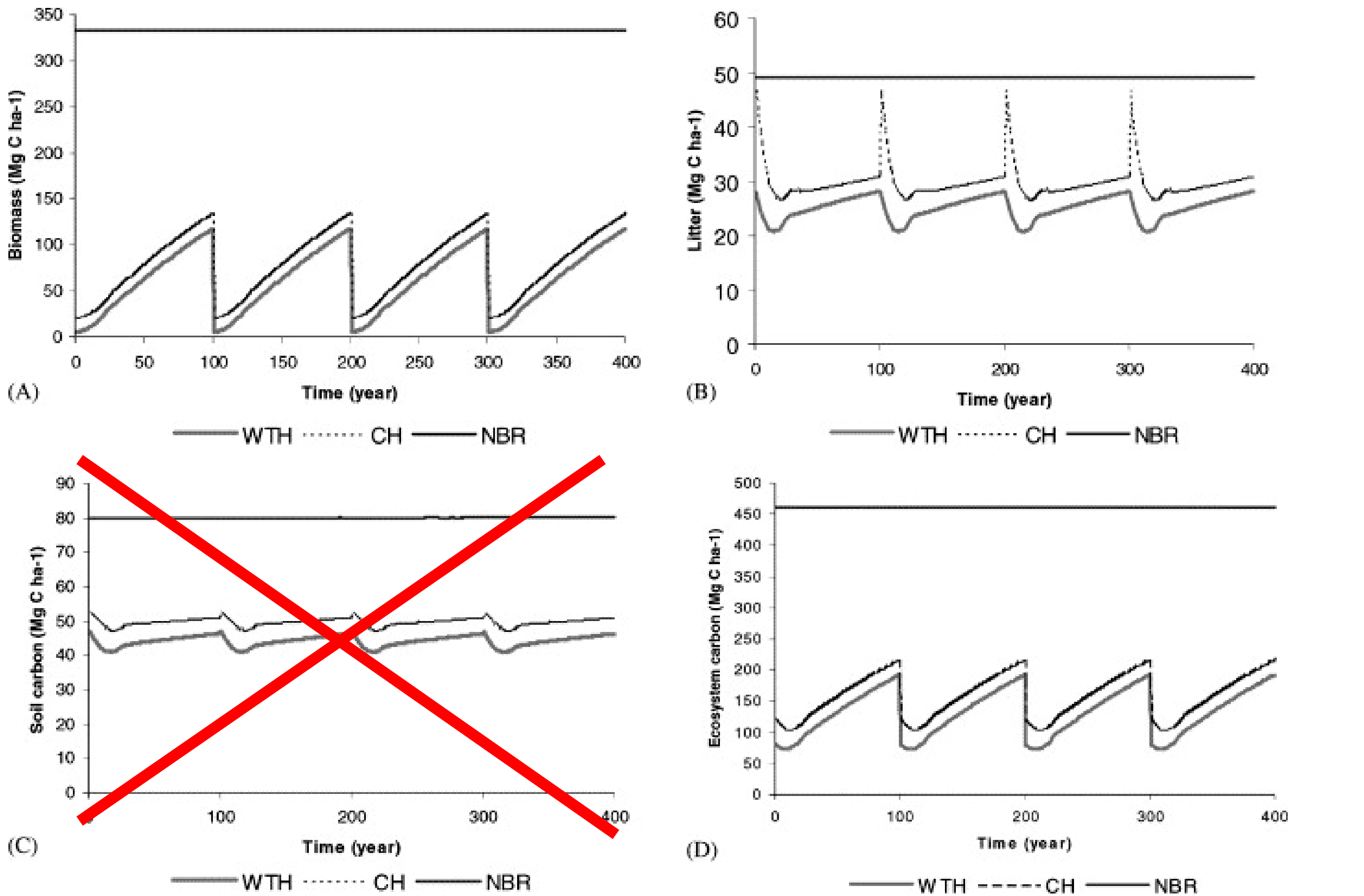
Scaling uncertainties

1. Site matching (SI= 88 in young and SI=66 in old)
   i. Bias towards more conservative
   ii. SI difference = *f*(soil, +25ppm CO_2, management history)
2. Fine woody debris
   i. Little direct contribution to rotation cycle C balance
   ii. Potential priming of SR by harvest residue
3. Extrapolation of biomass pools to maturity

Any biases would result in overestimating harvest residue and underestimating soil C loss.

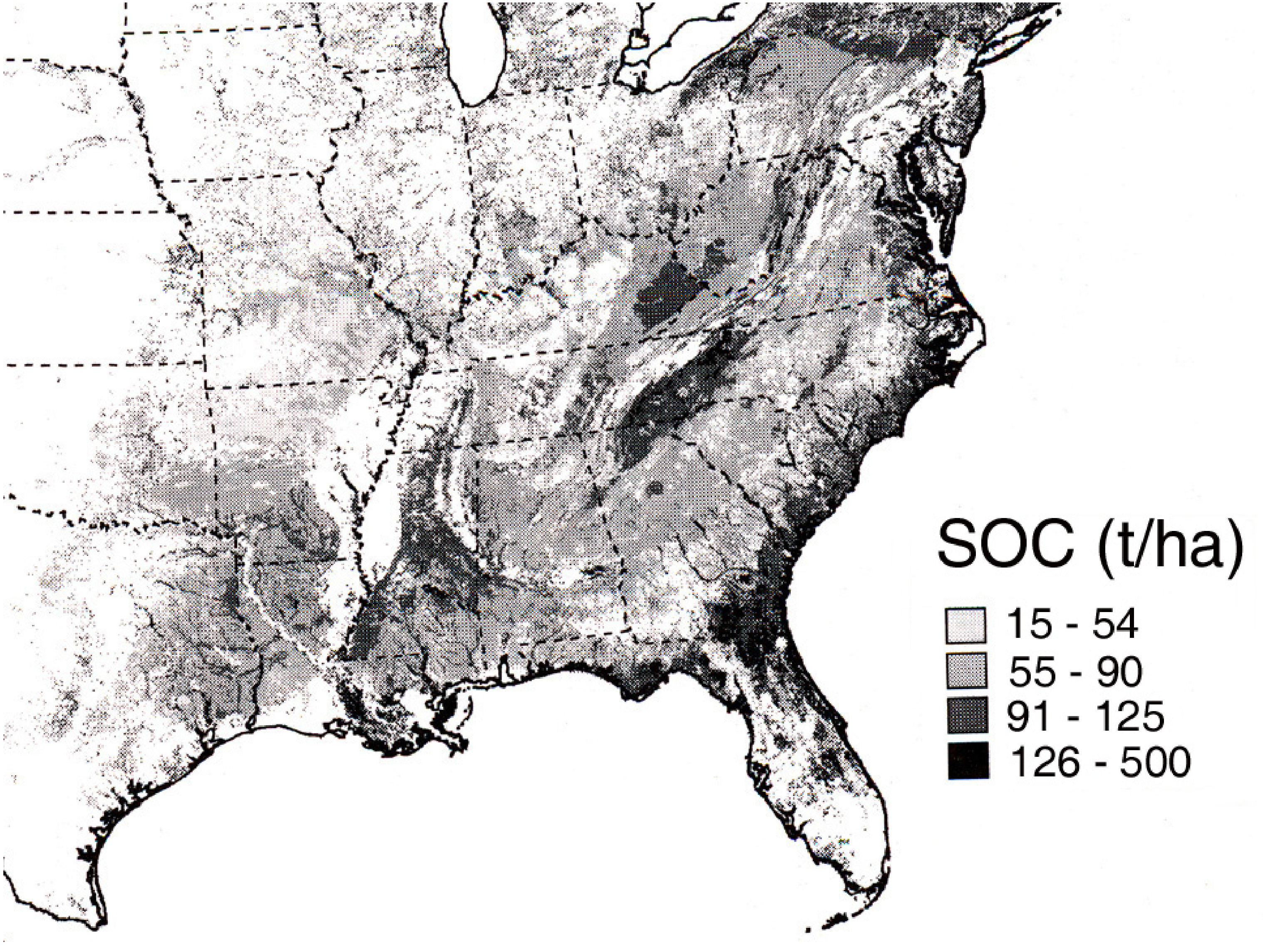
Respiration budget closed to within 10±5%.

Traditional view of soil C dynamics



Jiang et al., 2002, FEM

Soil carbon



Johnson & Kern (2003)

Next steps

- More detailed measurements of post-harvest C pools and fluxes in sites better matched in terms of soils
- Simulate the effects of different harvest lengths on different OM pools and evaluate the impact on productivity:sequestration tradeoffs
- Modified management may help reduce soil C losses while optimizing productivity
- This work can inform policy decisions for forest management