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

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Abstract

Timber harvests remove a significant portion of ecosystem carbon. While some of the wood products moved off-site may last past the harvest cycle of the particular forest crop, the effect of the episodic disturbances on long-term on-site carbon sequestration is unclear. The current study presents a 25 year carbon budget estimate for a typical commercial loblolly pine plantation in North Carolina, USA, spanning the entire rotation cycle. We use a chronosequence approach, based on 5 years of data from two adjacent loblolly pine plantations. We found that while the ecosystem is very productive (GEP up to 2900 g m 2 yr 1, NEE at maturity about 900 g C m 2 yr 1), the production of detritus does not offset the loss of soil C through heterotrophic respiration (R_H) on an annual basis. The input of dead roots at harvest may offset the losses, but there remain significant uncertainties about both the size and decomposition dynamics of this pool. The pulse of detritus produced at harvest resulted in a more than 60% increase in R_H. Contrary to expectations, the peak of RH in relation to soil respiration (SR) did not occur immediately after the harvest disturbance, but in years 3 and 4, suggesting that a pool of roots may have remained alive for the first few years. On the other hand, the pulse of aboveground R_H from coarse woody debris lasted only 2 years. The postharvest increase in R_H was offset by a decrease in autotrophic respiration such that the total ecosystem respiration changed little. The observed flux rates show that even though the soil C pool may not necessarily decrease in the long-term, old soil C is definitely an active component in the site C cycle, contributing about 25–30% of the R_H over the rotation cycle.

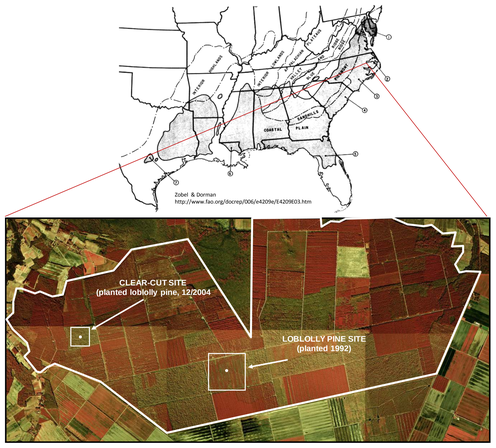

Fig. 1 The range of loblolly pine (top) and site locations at Parker Tract in Washington County, NC.

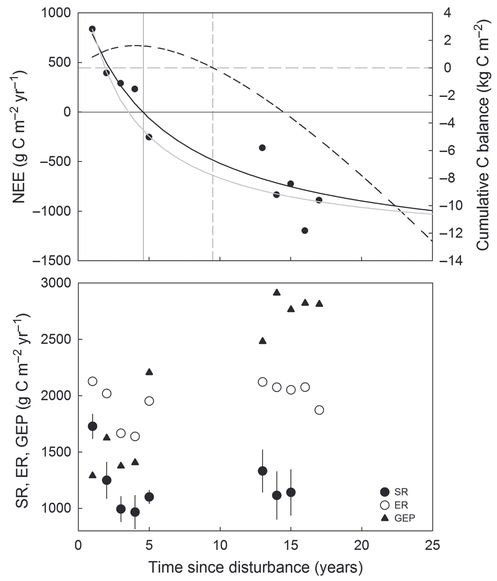

Fig. 2 Main ecosystem carbon fluxes over 5 years in two loblolly pine plantations of different age. (a) Annual and cumulative net ecosystem exchange (NEE) of CO2, with black line indicating a rectangular hyperbola model, fitted to all the measurements, the black dashed line marks cumulative carbon balance, and the gray line is a rectangular hyperbola fitted to non-drought-year data. (b) Ecosystem respiration (ER), soil respiration (SR), and gross ecosystem production (GEP).

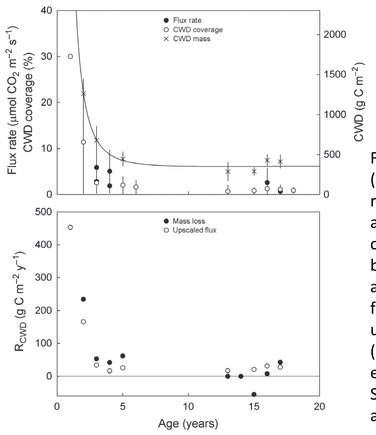

Fig. 3 Coarse woody debris (CWD) decomposition (RCWD; rates for decay classes 2 and 3 are shown), CWD areal coverage, and total CWD biomass (a), and the derived area-normalized RCWD derived from CWD loss rate and from upscaled CO2 emission rates (b). The fluxes are presented as estimates of CO2 emissions. See Methods for further details and assumptions.

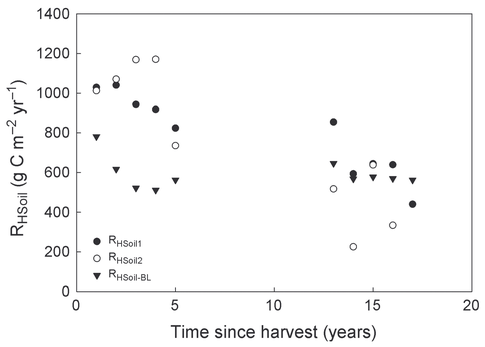

Fig. 4 Belowground heterotrophic respiration (RHSoili; see Eqn 3a–c) from three different approaches in two loblolly pine stands. Years 1–5 come from US-NC1, years 13–17 from US-NC2.

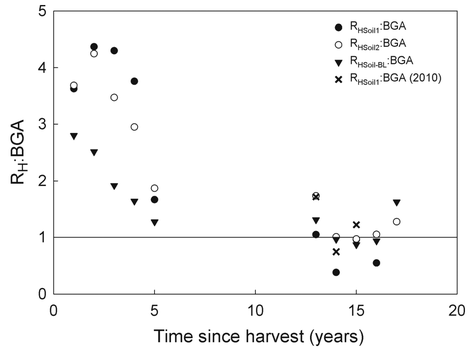

Fig. 5 The ratio of annual soil carbon losses (RHSoil) to inputs (BGA) in two loblolly pine plantations. Years 1–5 come from US-NC1, years 13–17 from US-NC2. BGA includes leaf, fine and coarse root production and branchfall. Crosses represent values based on earlier NPP estimates (Noormets et al., 2010) using higher biomass carbon content.

References

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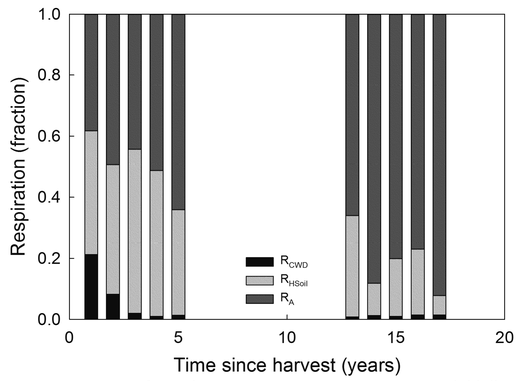

Fig. 6 Partitioning of total ecosystem respiration in two loblolly pine plantations. Years 1–5 come from US-NC1, years 13–17 from US-NC2. RA is the average of biometric and global estimates (RA1 and RA2, see Methods), RHSoil is estimated as the residual.

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 CO2, management history)
2. Fine woody debris
   i. Little direct contribution to rotation cycle C balance
   ii. Potential priming of SR by harvest residue
3. CWD fragmentation
4. 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%.

Findings

1. R_A:GEP=0.6 at maturity, increases with age.
2. Harvest-related spike in R_H peaks 3-4 years after harvest.
3. Lag in R_H peak may obscure broad patterns in meta-analyses.
4. R_H and inputs of harvest residue suggest losses exceeding inputs (by about 50-100 g C m^{-2} yr^{-1}), but uncertainties in key processes are too high to know it with certainty.

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