Simulating the Impacts of Woody Biomass Harvesting on North Temperate Forest Carbon and Nitrogen Cycling and Storage

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Outlines

- Motivation
- Methodology
- Model description
- Simulation results
- Conclusions
- Future work

Motivations

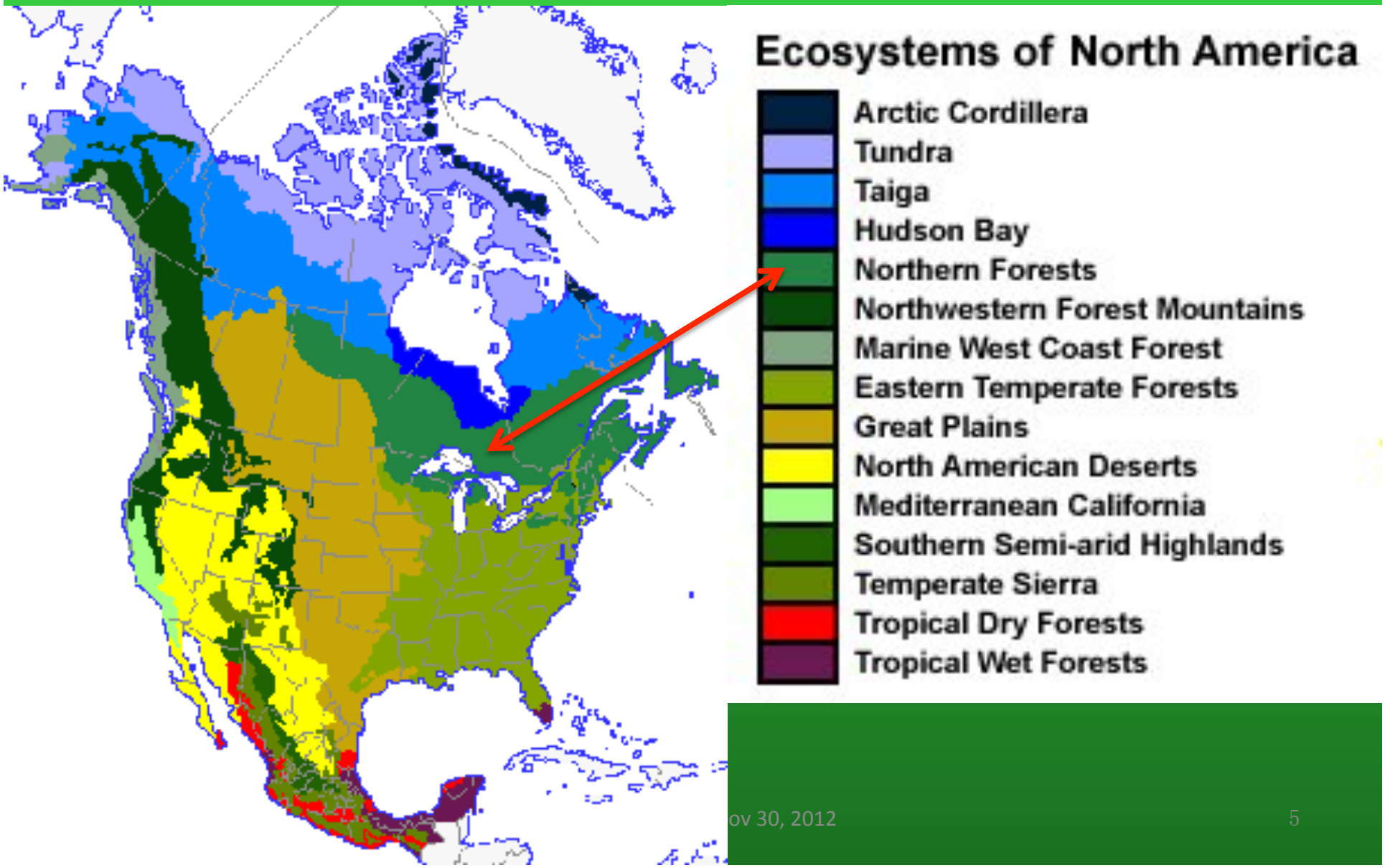
- How the role of forest ecosystems in carbon sequestration would be altered by woody biomass harvesting and how this would influence future climate change?
- What would be short and long term responses of forest ecosystem carbon (C) and nitrogen (N) to biomass harvesting?
- Can we provide a framework for incorporation of carbon management and sustainable forest management practices?

Why north temperate forests

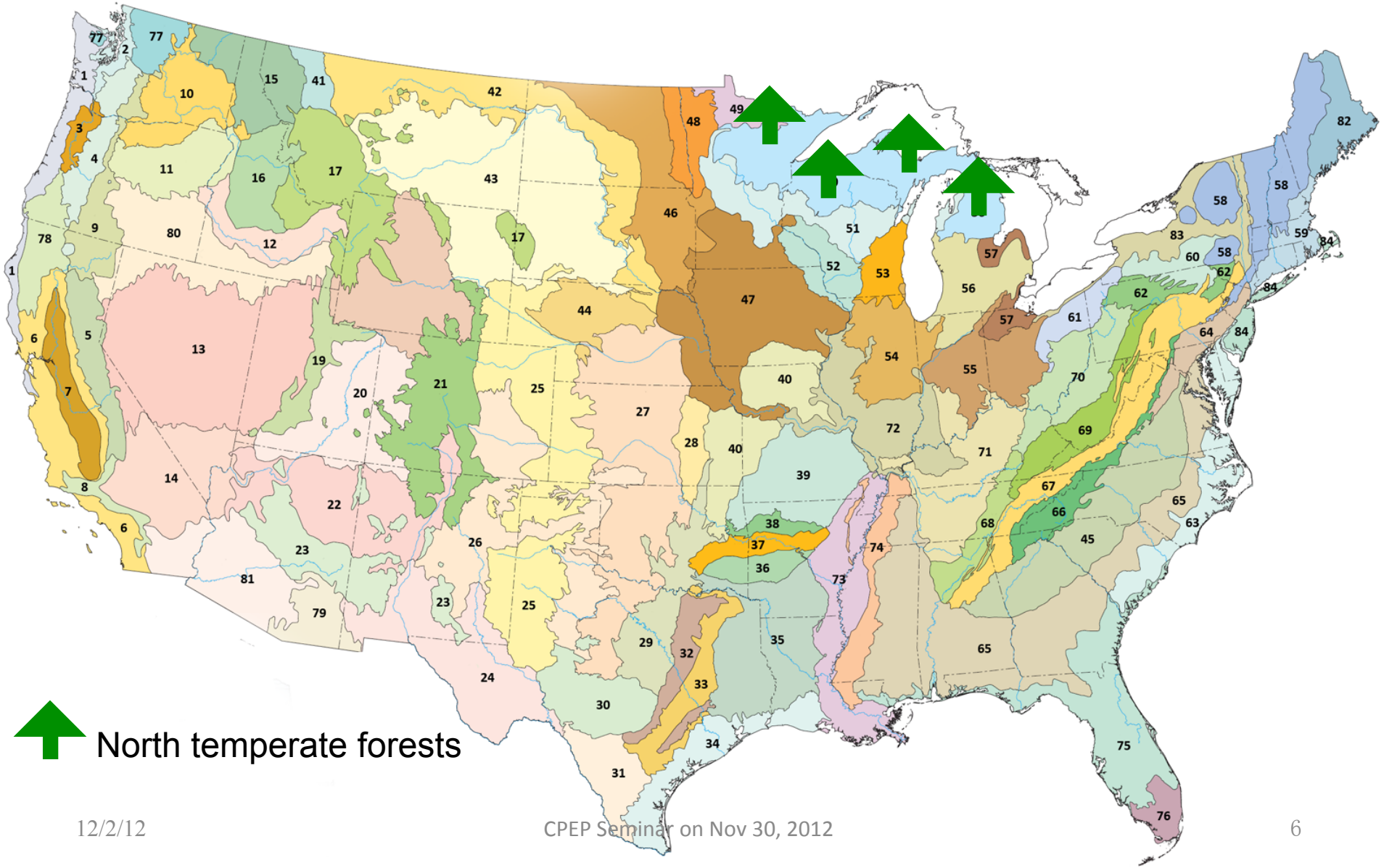
- North temperate forests cover ~29 million ha or 9.6% of forested area of the United States
  - Birdsey, 1992; USDA Forest Service, 2001
- An important terrestrial carbon reservoir and a sink of atmospheric CO_2 for North America

  Sedjo, 1992; Birdsey et al., 1993; Tkacz et al., 2007

Ecoregion in North America



North temperate forests in US



Why models?

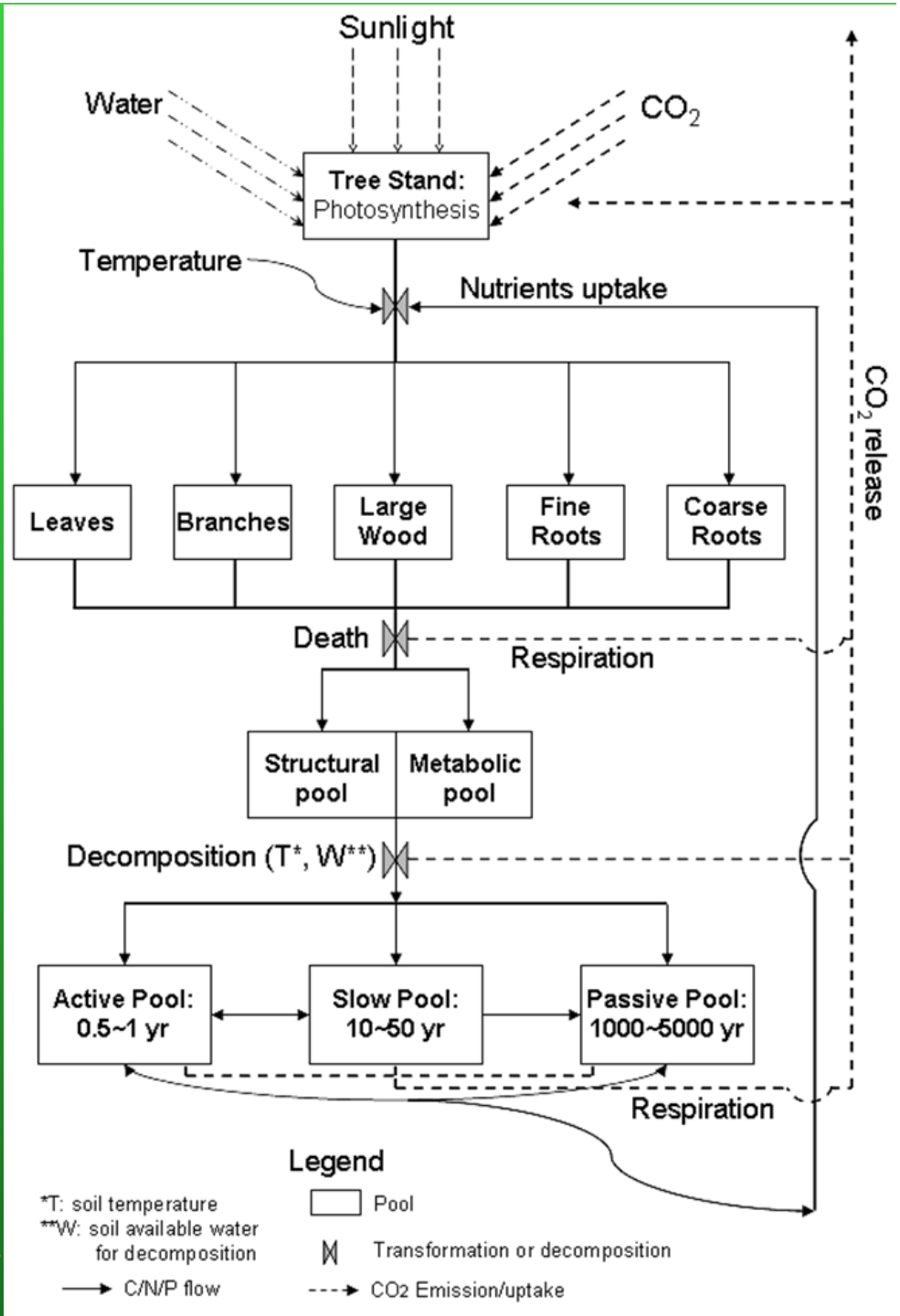
- A good substitute for field experiments
- Cost effective and time efficient
- Predictive capability

The CENTURY model (Parton et al. 1993) was modified and used in this study

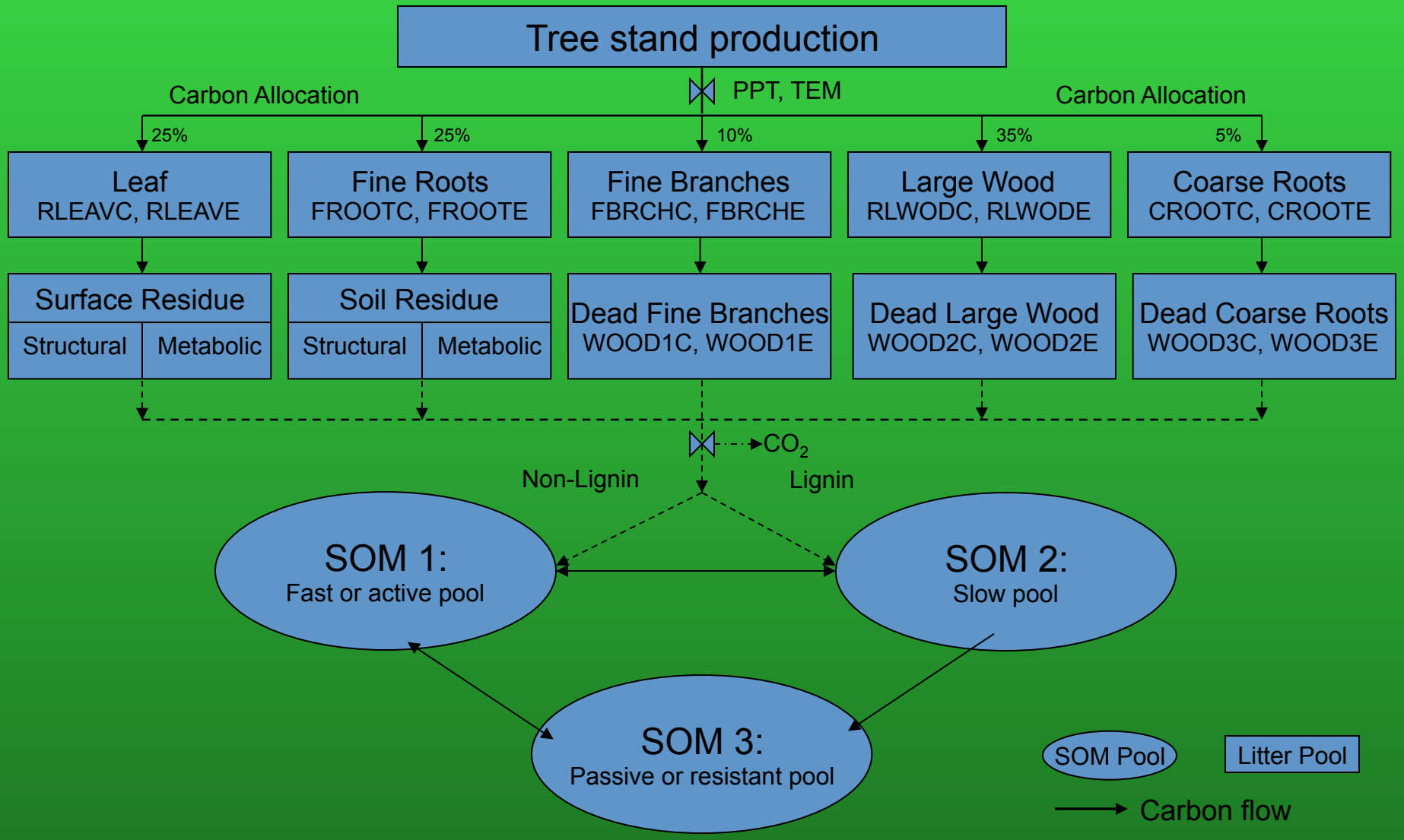
The model

- A process-based model
- Aboveground processes: photosynthesis, tree growth/death
- Belowground processes: root growth/ death, litter decomposition, soil organic carbon (SOC) pools
- Disturbance: fire, insect, and harvesting

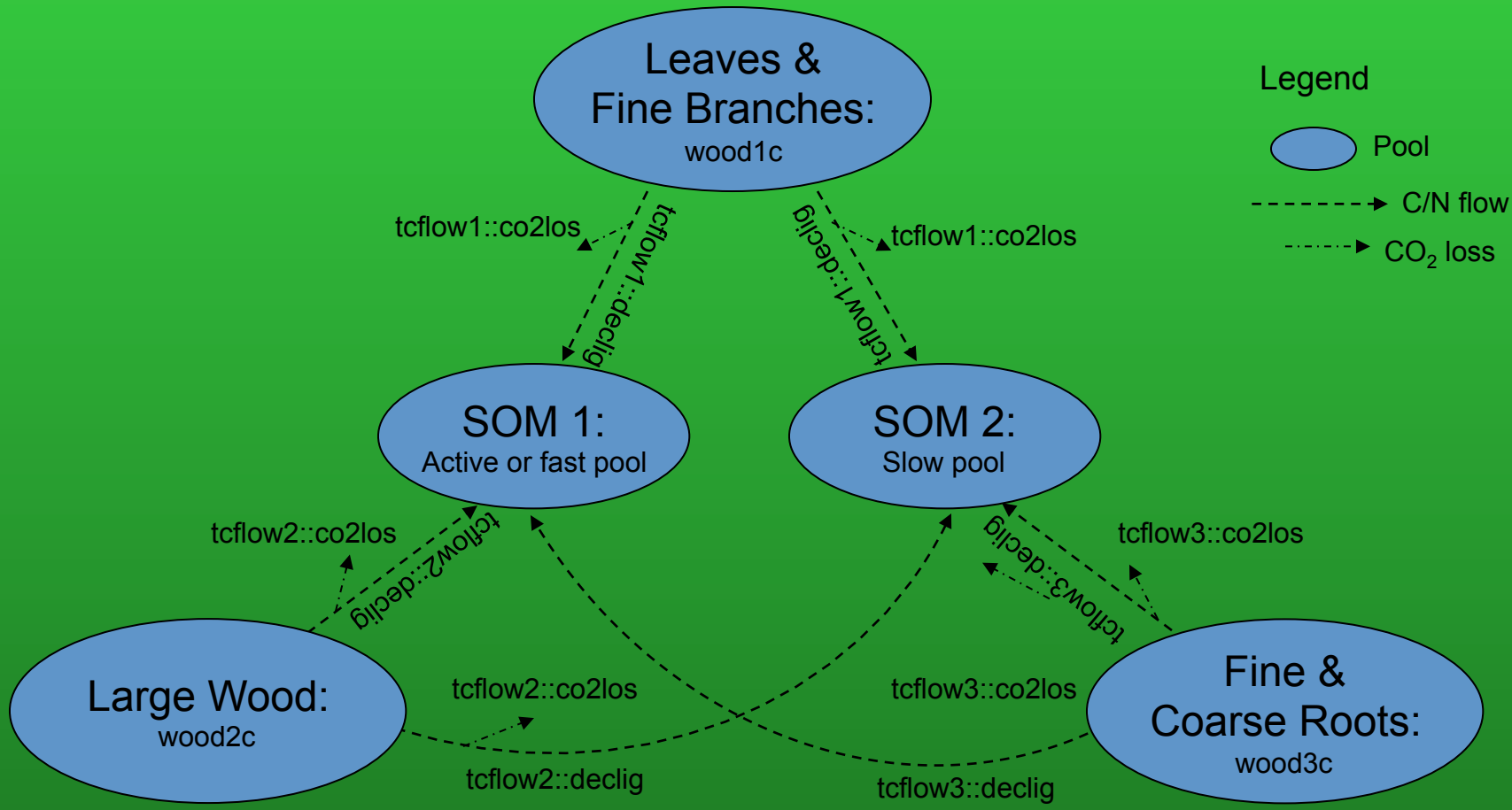
Model structure



CENTURY and its sub-modules



C/N flows among litter Pools and soil organic C pools



What is new in our model?

- Module for calculation of CO_2 exchange between terrestrial biosphere and the atmosphere has been developed
- Module for calibration of the model parameters has been developed
- Module for sensitivity analysis of the model variables has been developed

From forests

Lumber

Paper

Biofuel

Harvesting types: clear cut

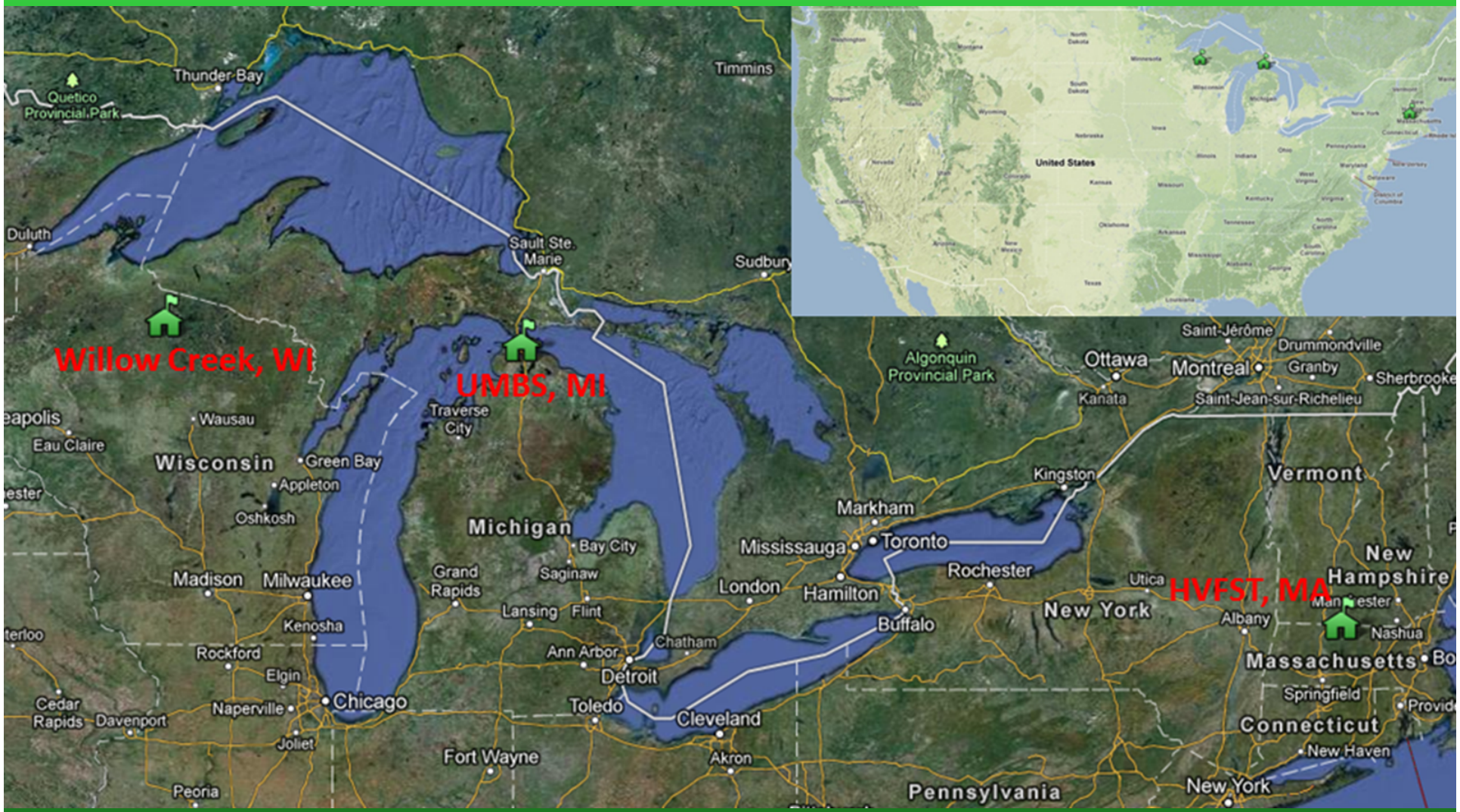
Partial harvesting

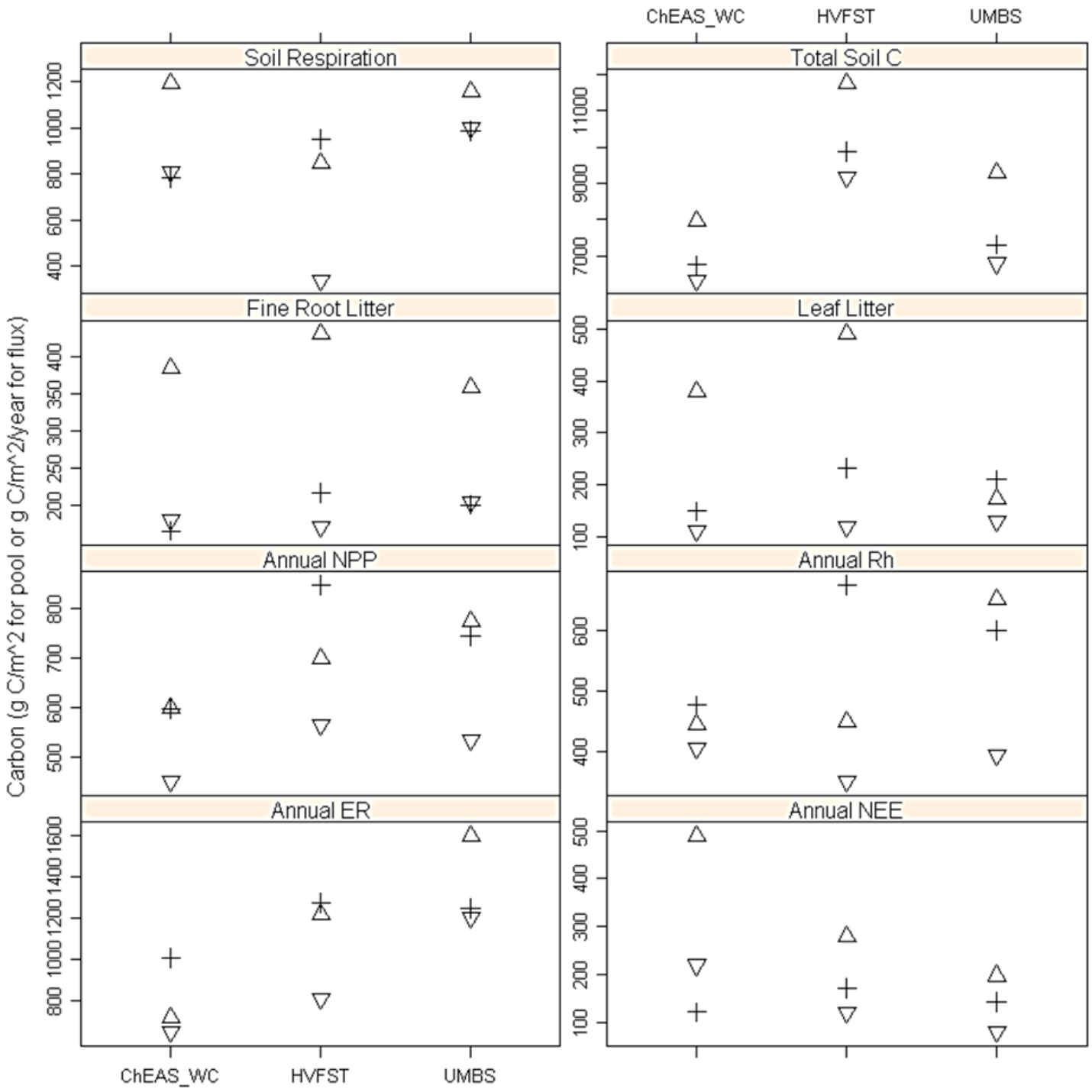
Study site: Willow Creek

- An upland hardwood forest in northern Wisconsin
- Primary tree species: sugar maple (Acer saccharum)

CO_2 flux tower at Willow Creek
(Photo from ChEAS website)

Model validation sites





Model simulation vs field measurement

△ Maximum value in measurements

\+ Model simulation

▽ Minimum value in measurements

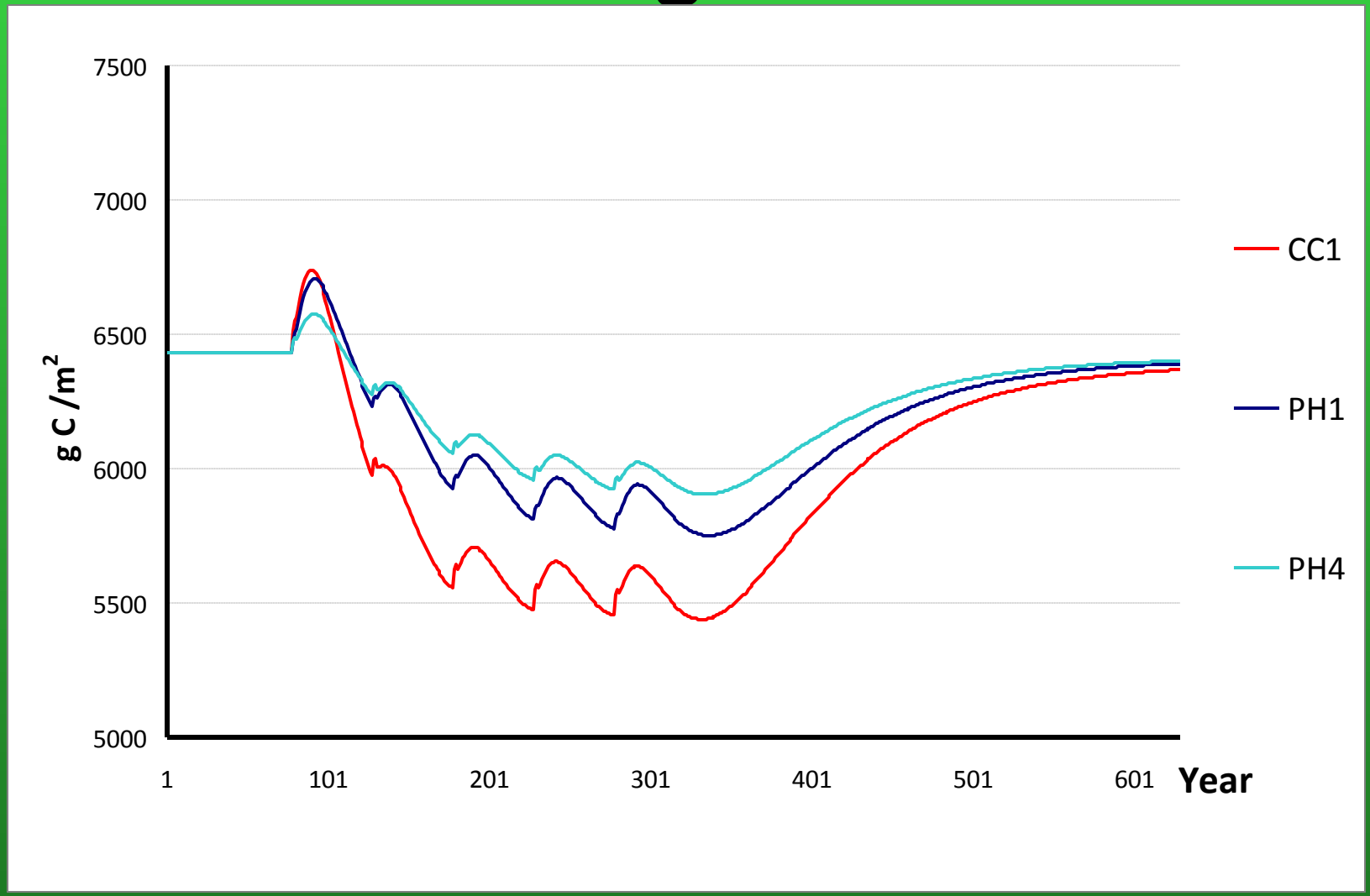
Biomass harvesting types in test

Harvesting intensity

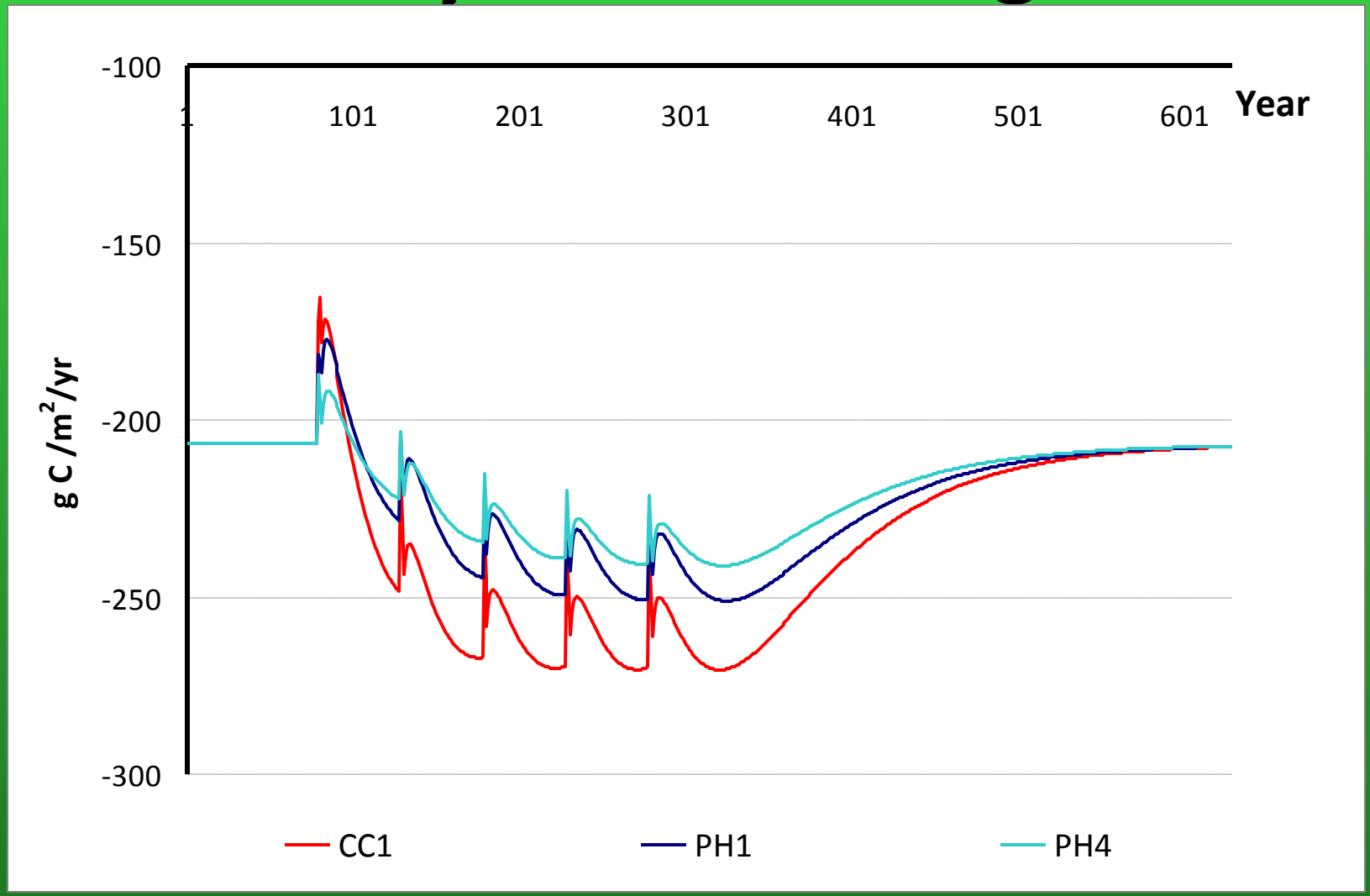
Type/Fraction Removed (%)	Leave	Fine branch	Large wood	Fine litter	Coarse litter	Approach
Uniform clearcut 1 (CC1)	100	100	100	90	70	Remove entire stand in one cut
Uniform clearcut 2 (CC2)	100	100	100	0	70	Remove entire stand in one cut, fine litter left
Uniform clearcut 3 (CC3)	100	100	100	90	0	Remove entire stand in one cut, coarse litter left
Alternate clearcut (ACC)	50	50	50	45	40	Remove entire stand in two cuts during 2 yrs
Partitial harvest 1 (PH1)	80	70	60	90	20	Moderate removal of aboveground biomass
Partitial harvest 2 (PH2)	80	70	60	0	20	Small removal of underground biomass
Partitial harvest 3 (PH3)	80	70	60	90	0	No underground biomass removal
Partitial harvest 4 (PH4)	60	50	40	90	20	Minimum removal of aboveground biomass

Weak

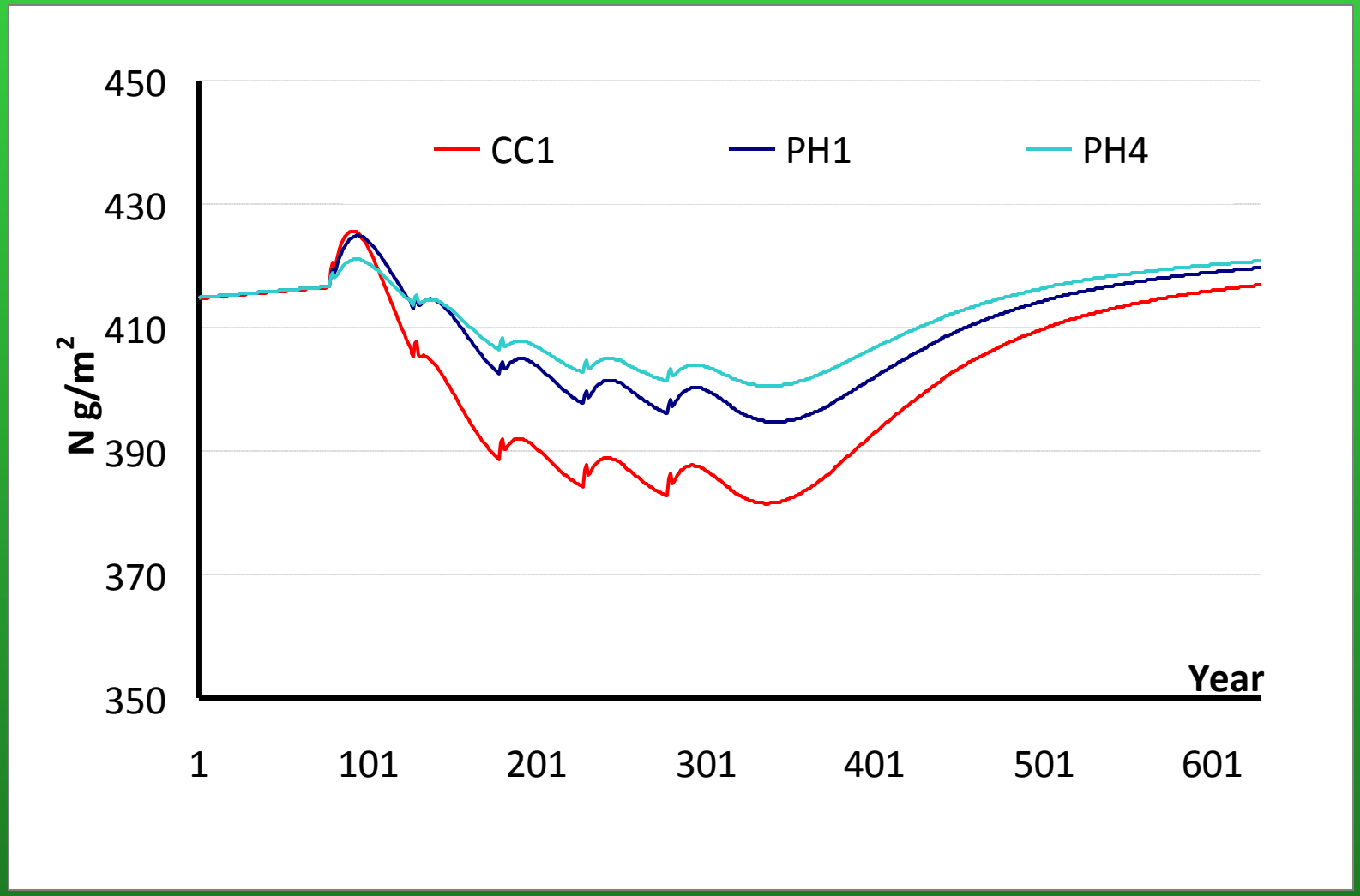
Total soil organic C: TOC



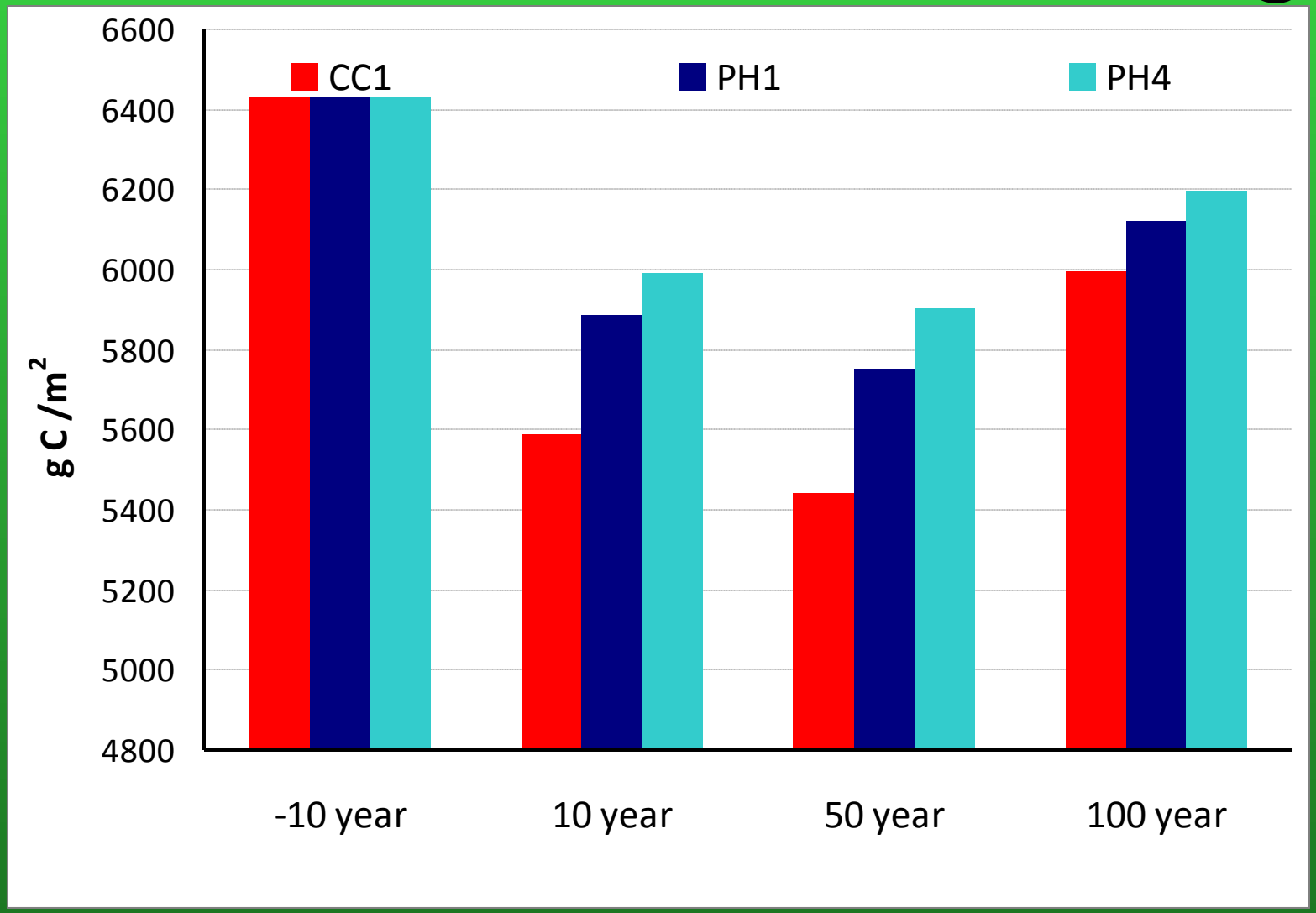
Net ecosystem exchange: NEE



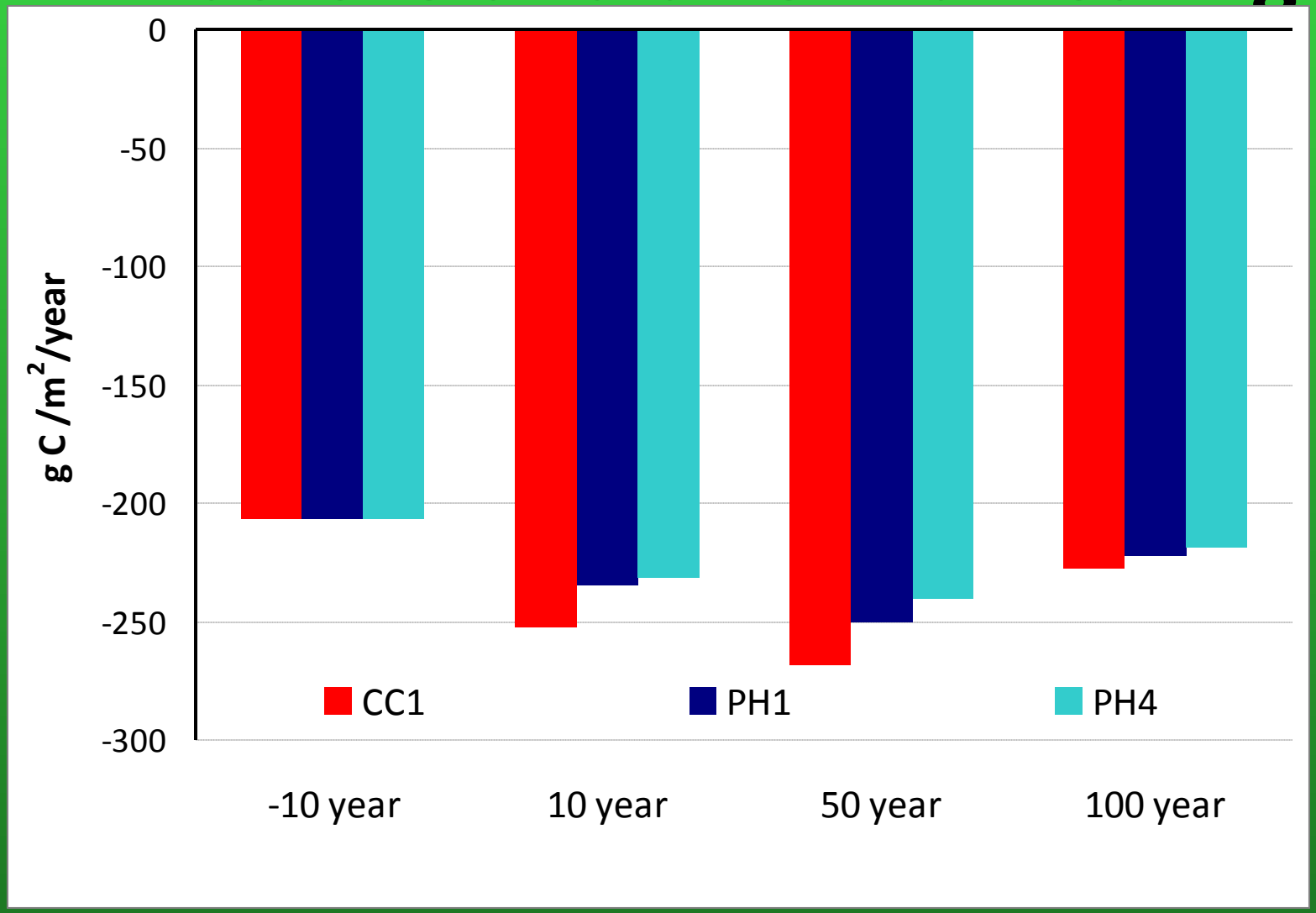
Total soil nitrogen (TSN)



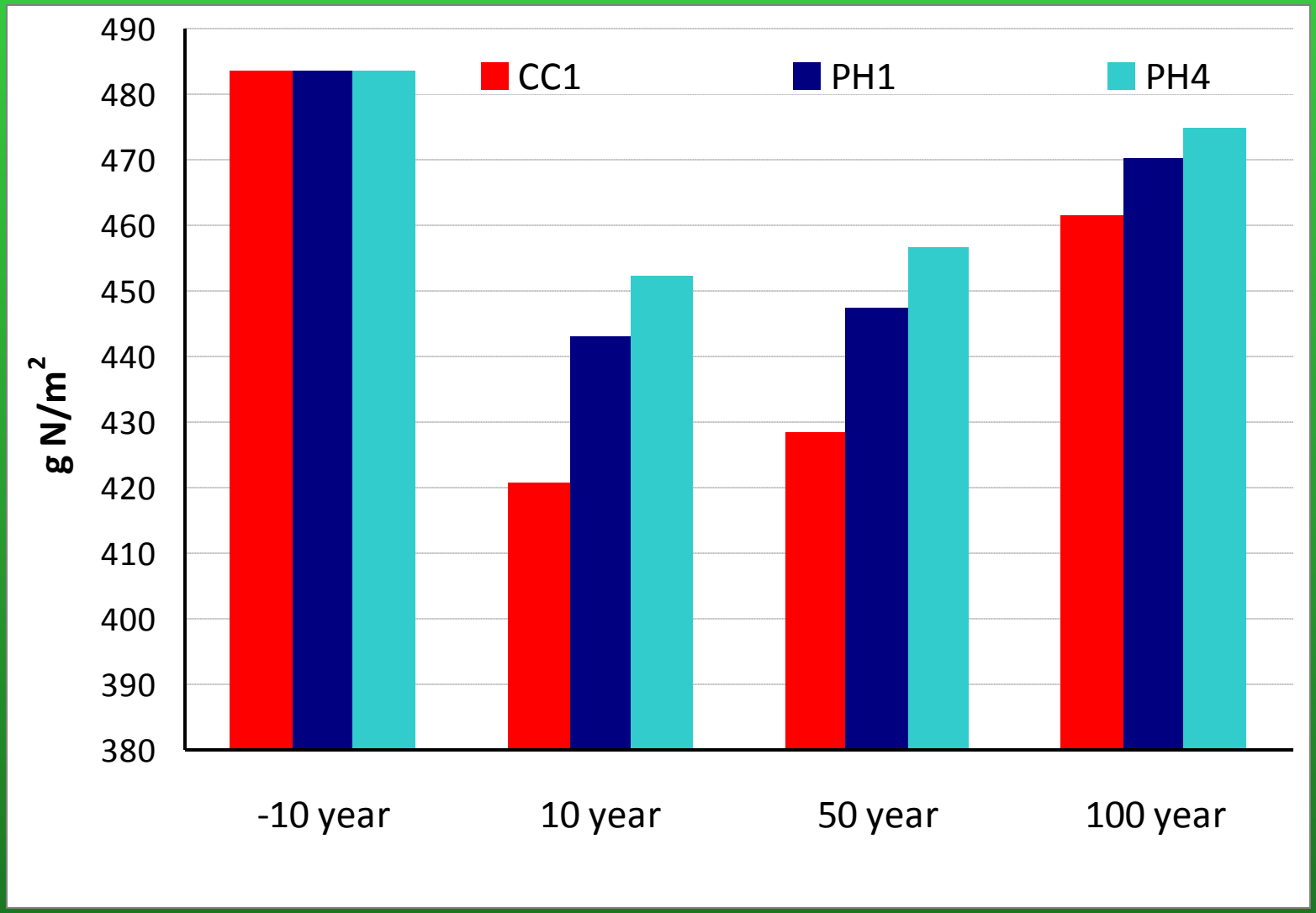
TOC before and after harvesting



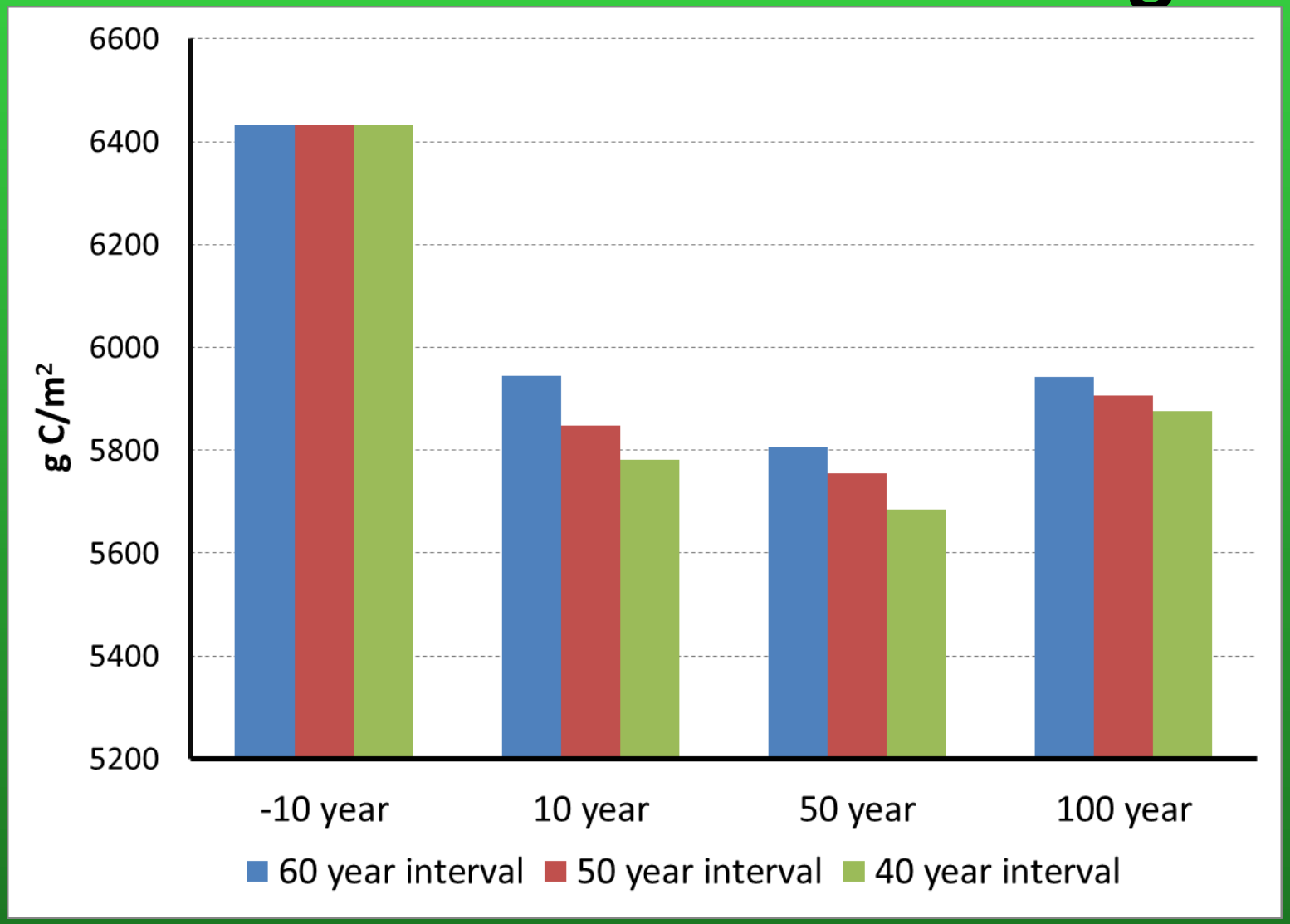
NEE before and after harvesting



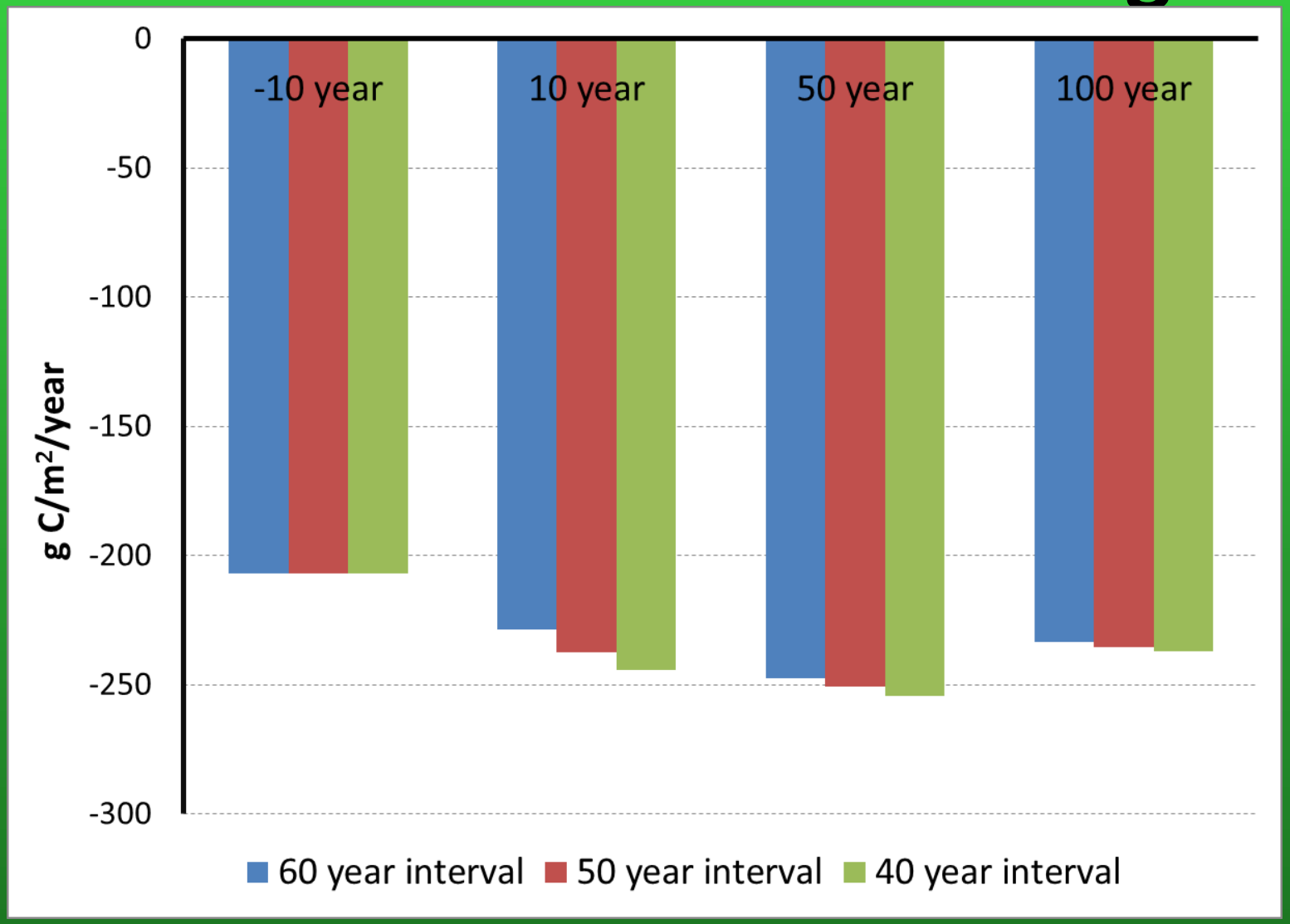
TSN before and after harvesting



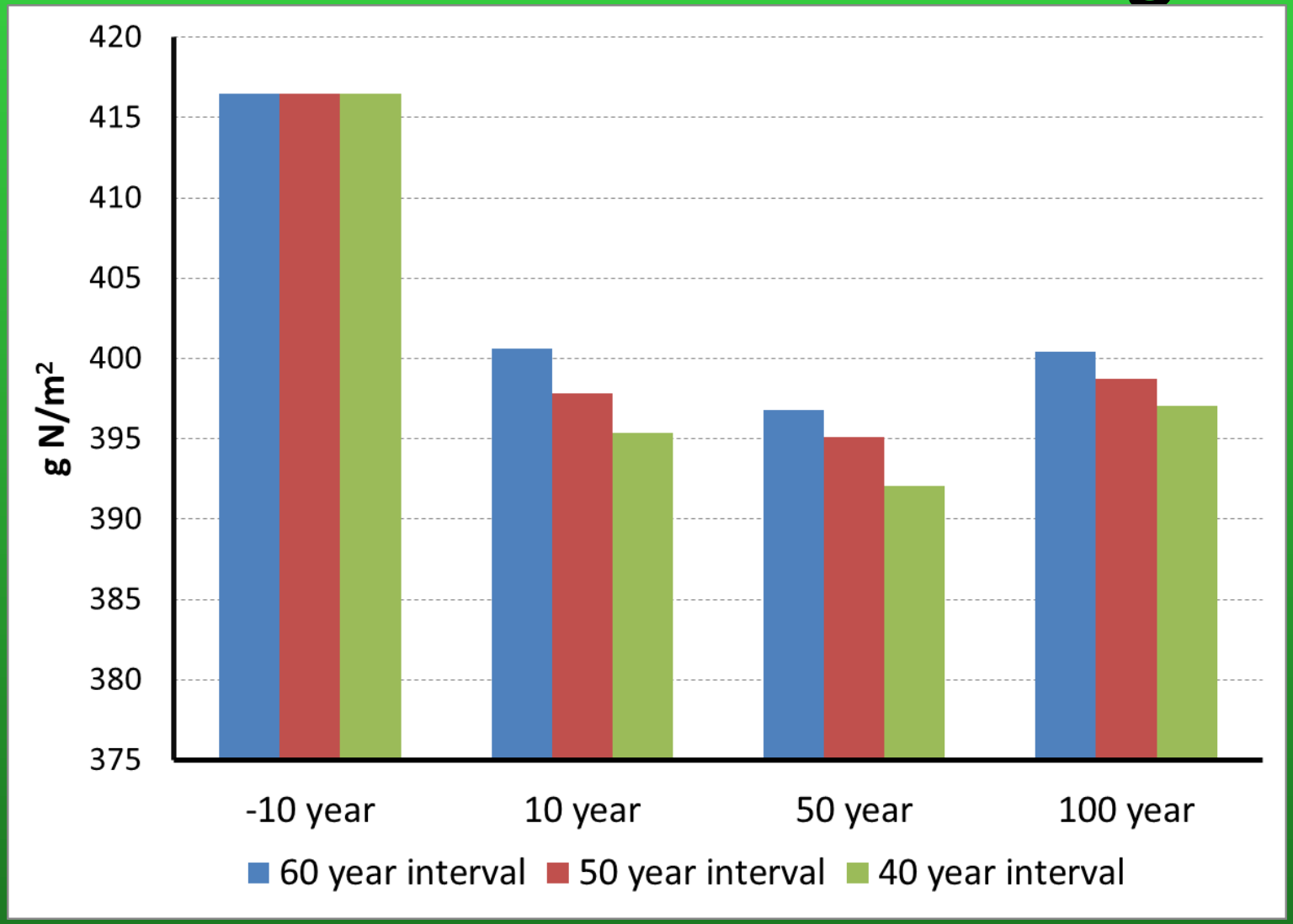
TOC under PH1 harvesting



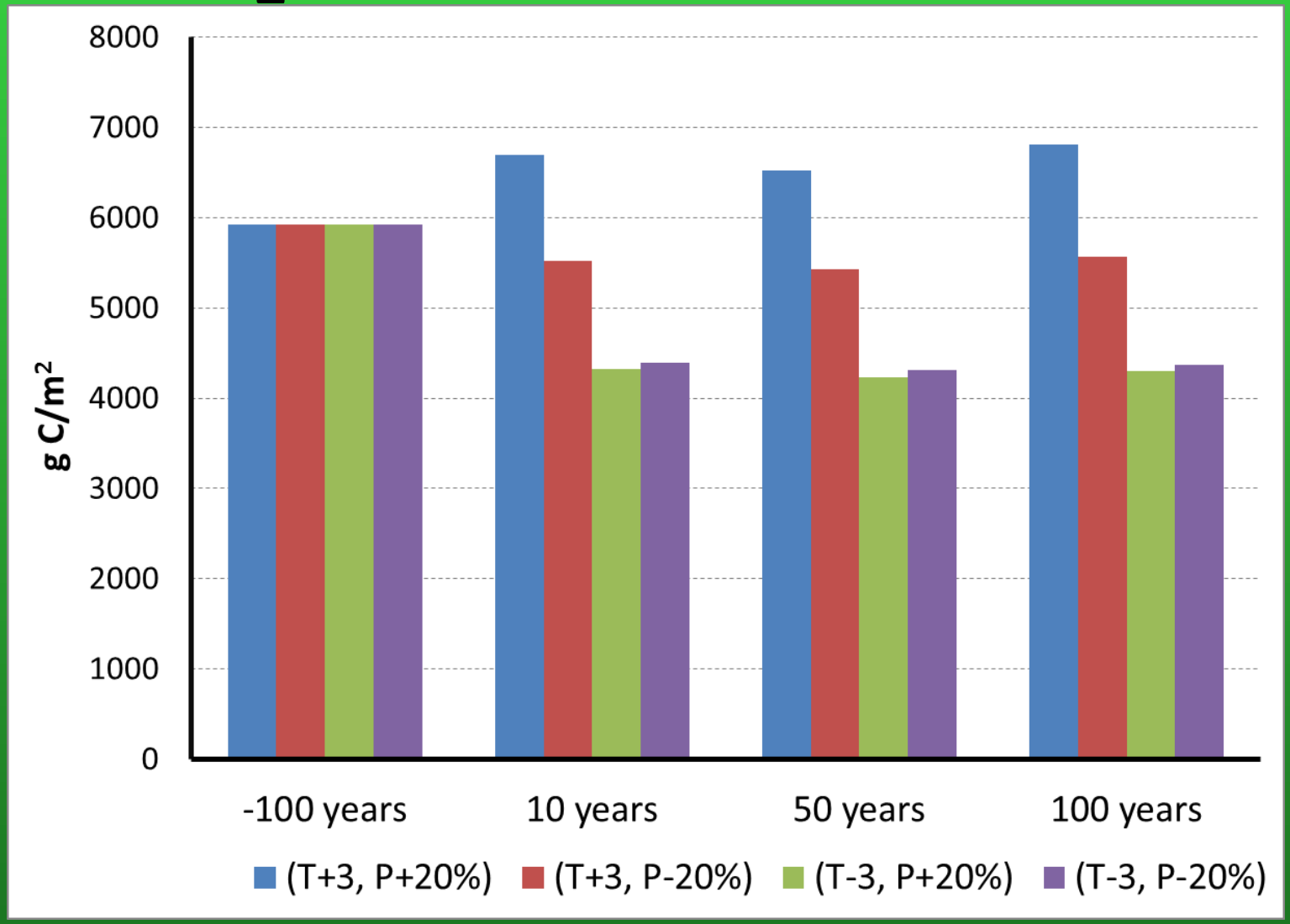
NEE under PH1 harvesting



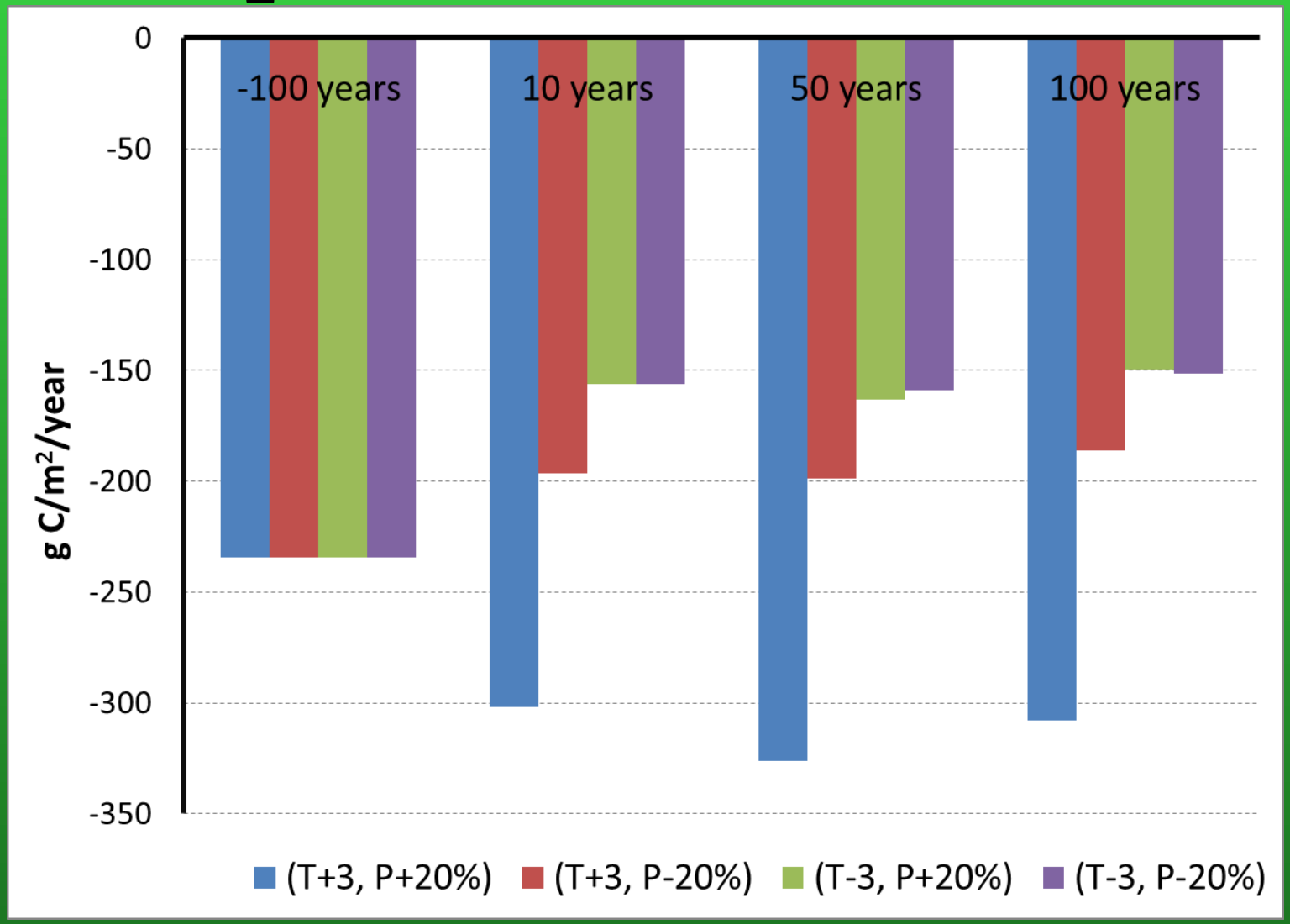
TSN under PH1 harvesting



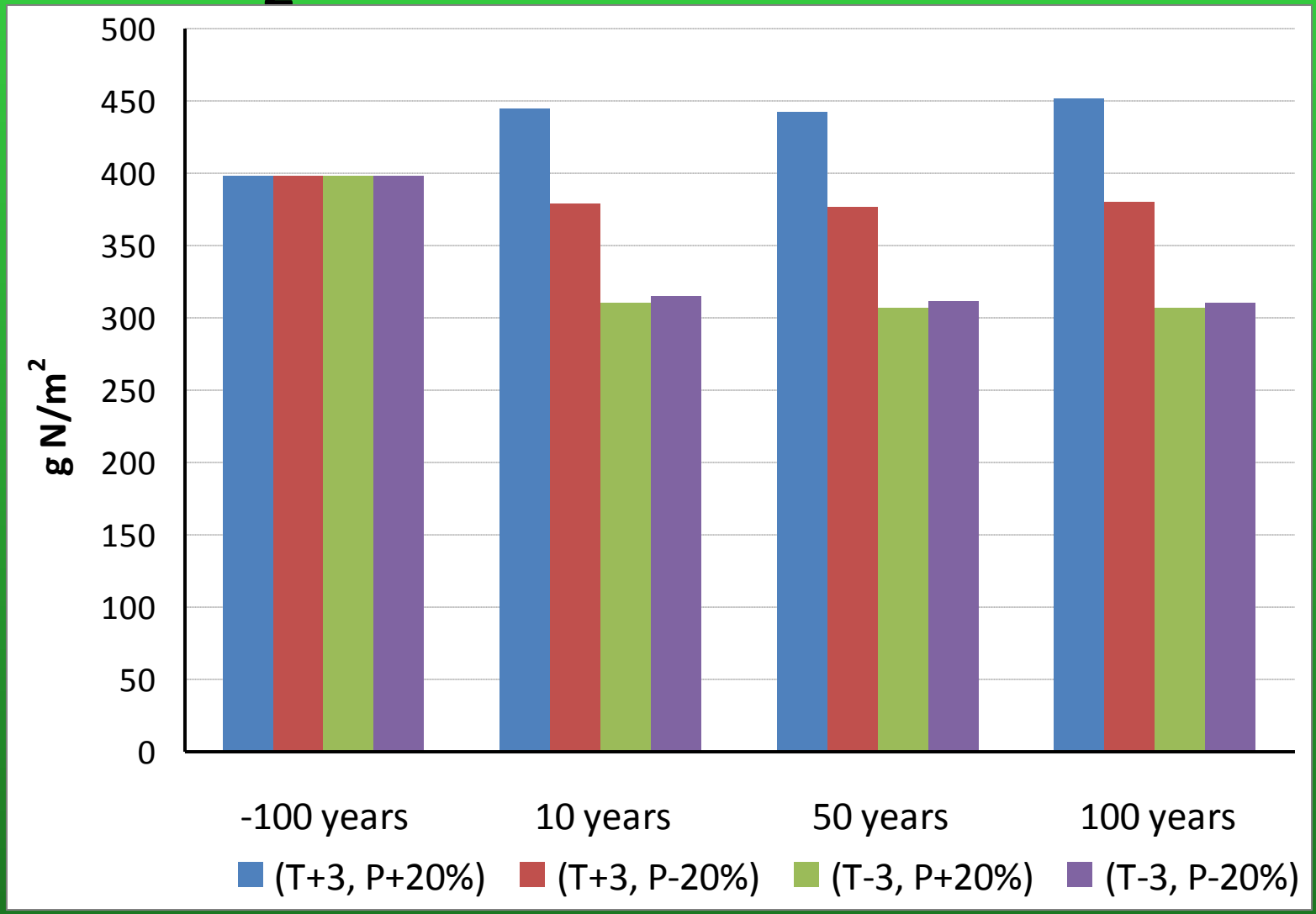
2xCO_2 plus T and P: TOC (PH1)



2xCO_2 plus T and P: NEE (PH1)



2xCO_2 plus T and P: TSN (PH1)



Conclusions

- Woody biomass harvesting can stimulate a short-term soil C/N storage and uptake, but C/N storage declines in the long run
- Harvesting intensity is proportional to long-term decline of soil C/N storage

Conclusions (cont'd)

- Partial harvesting with most of litter remaining on site favors the restoration of forest ecosystem C/N in a relatively short period
- The longer the harvesting interval, the less loss of C/N in forest ecosystems and the faster C/N storages restore to the pre-harvesting conditions

Conclusions (cont'd)

- Under doubling the CO_2 concentration, changes in air temperature may cause more significant variations of C/N storage and uptake in forest ecosystem than changes in precipitation. Warm temperature is more favorable for C/N storage than cool temperature

Future work

- How to make balance between C sequestration and biomass harvesting in forest management
- Investigating the responses of different tree species to biomass harvesting
- Exploring the effects of harvesting on C/N cycling and storage with intra-annual variation of temperature and precipitation

Acknowledgements

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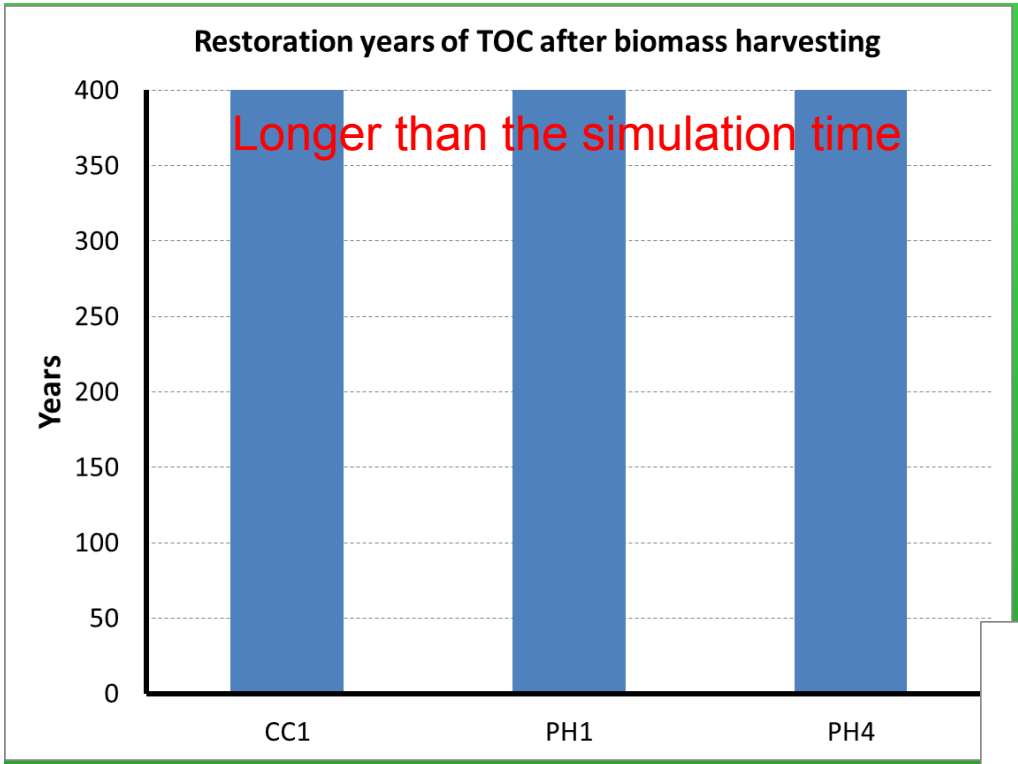
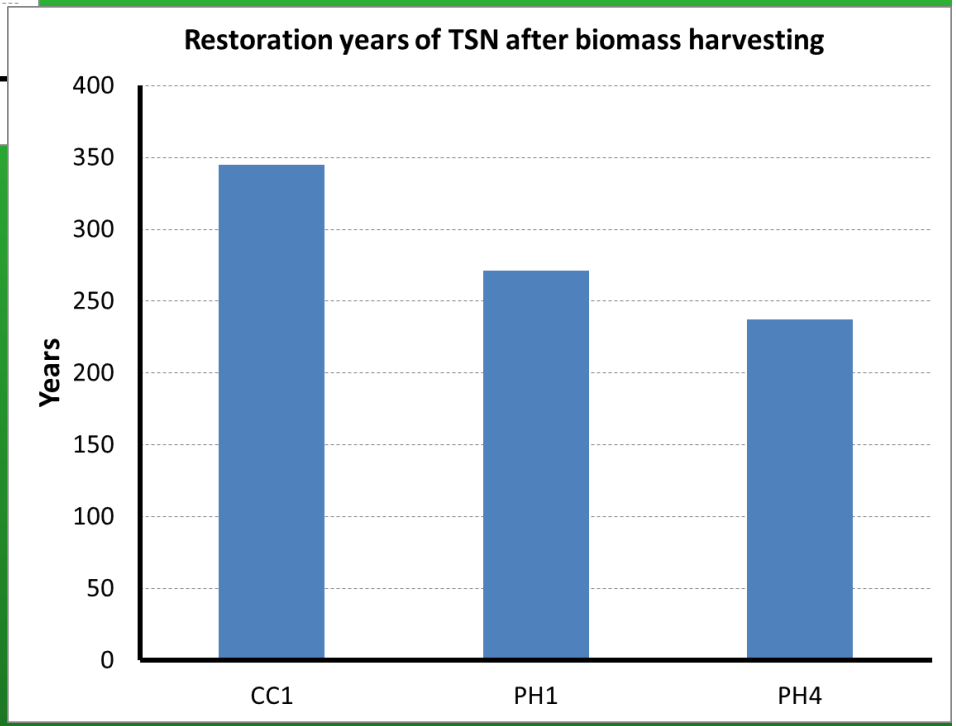
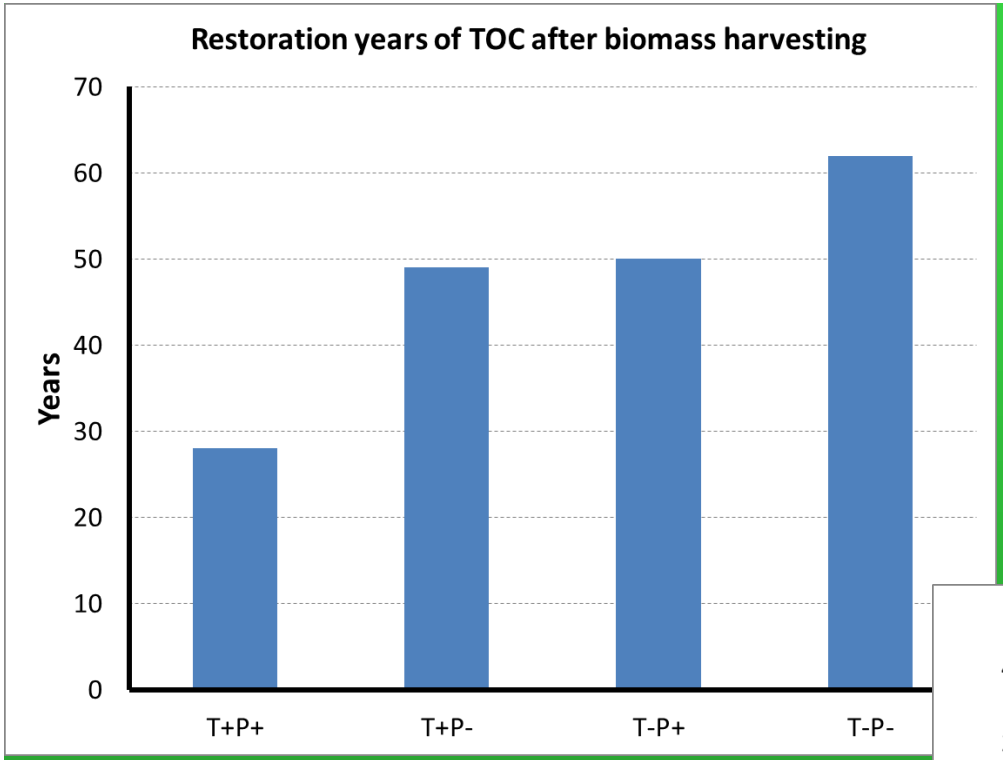
Photo taken at Willow Creek, WI, in Sept 2012



Restoration of C/N back to pre-harvesting conditions



50-year harvesting interval



Future Climate Change: 2xCO_2 concentration

Under CC1 harvesting