Spatial Biological and Industrial Carbon Budgets for Northern Wisconsin

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Abstract

We used satellite remote sensing data as inputs to a forest ecosystem process model that simulates carbon budgets and major carbon (C) fluxes for a national forest, state forest, and non-industrial private forest in Wisconsin. Forest management practices were incorporated into the model to assess carbon cycling and sequestration at the landscape scale for future climate change scenarios. Output from the forest ecosystem process model was compared to timber harvest data and input to a life cycle analysis of forest product chains to quantify sources of greenhouse gas emissions. The proportion of industrial C emissions to biological carbon sequestration ranged from 0.01% to 0.65% for all scenarios at the landscape scale. Using output from the ecosystem model and life cycle analysis, we discuss opportunities in forest management and forest product–related industrial sectors that can be modified to (i) increase carbon sequestration or (ii) mitigate greenhouse gas emissions.

Introduction

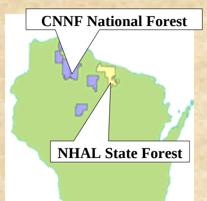
- The **objective** of this ongoing project is to quantify all C fluxes, both positive and negative, associated with the biological and industrial carbon cycle of a national and state forest using ecosystem modeling and life-cycle inventory methodologies.

The forest C cycle links two major components, the forest ecosystem C cycle and forest industrial C cycle including greenhouse gas emissions (Figure 1). Carbon sequestration (C_{seq}) can be calculated from net primary production (NPP) and heterotrophic respiration (Rh) and then used as input into life cycle analysis of wood and paper product chains. Greenhouse gas emissions (GHG) are calculated for each process of the chain.

Approach

Biological Carbon Cycle

Landcover and leaf area index products derived from the MODIS satellite sensor were used as input to the ecosystem process model, BIOME-BGC (Thorton et al. 1998; Bond-Lamberty et al. 2005). We focused our initial simulations on the Chequamegon-Nicolet National Forest (CNNF) and the Northern Highland American Legion State Forest (NHAL) to coincide with data collected for the industrial carbon cycle (below). Harvest data collected from each forest were used directly in BGC to simulate the effects of differing harvest intensities on the net ecosystem production (NEP, carbon sequestration) over 60 years. Present day climatology data were acquired from the UW-AWON, ASOS, and AWOS weather networks. Soils and soil carbon data were derived from STATSGO. All spatial data were registered to 1-km statewide grid established for simulations. Climate change data from the Hadley Climate Centre (Johns et al. 1997) were incorporated into the model to simulate the effects of changing temperature, precipitation, and atmospheric CO_2 on the combined biological and industrial carbon cycle.



Approximate forest locations within Wisconsin

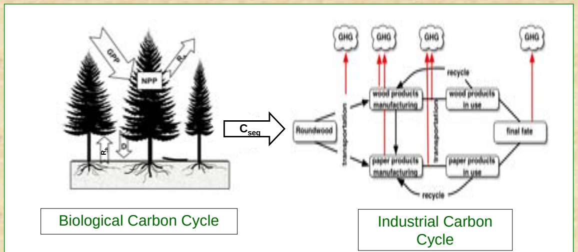


Figure 1: Forest Carbon Cycle (Gower, 2003)

Industrial Carbon Cycle

Two processes in the industrial forest carbon cycle were analyzed using Life-Cycle Inventory (LCI) (Figure 2). The study boundaries for the harvest process life-cycle inventory (LCI) include the carbon fluxes associated with three forest ownerships; NHAL, CNNF, and the non-industrial private forests (NIPF) that participate in the managed forest laws (MFL's) of Wisconsin. The study boundaries for the primary mill process LCI include the carbon fluxes associated three mill types; two chip board mills (OSB A&B), and dimensional lumber mill (DL A), and a pulp/paper mill (DL B).

Data were collected from timber sale cutting reports, law records, mill personnel and a questionnaire. The calculation was completed for four years, 2000-2003. Carbon flow within the harvest process was calculated by tracking volumes of roundwood harvested, time harvest machinery was in use, fuel economy of machinery regimen, roundtrip distance purchasers traveled to site, volumes of roundwood exported from state, and roundtrip distance truckers travel from site to mill. Carbon flow within the primary mill process was calculated by tracking volumes of roundwood processed, volumes of imported roundwood, and fuel and electricity use.

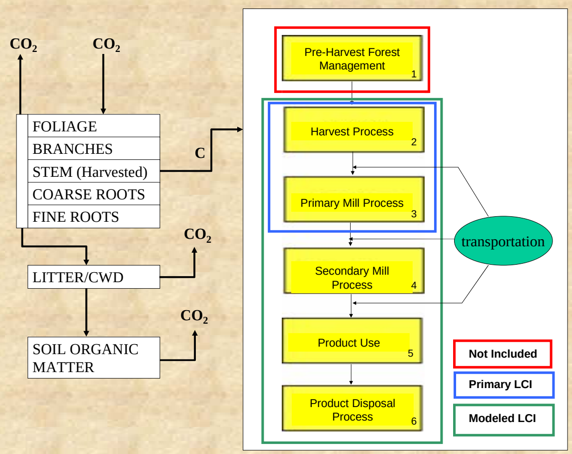


Figure 2: Pools and C fluxes of the ecosystem model (left) used to simulate effects of harvesting on net ecosystem production. The industrial forest carbon budget boundaries of investigation (right).

Results

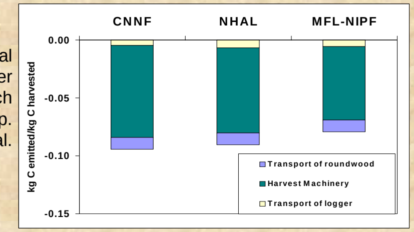


Figure 3: Total carbon emitted per harvested C for each forest ownership. Data from White et al. 2005.

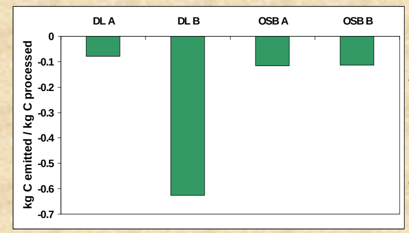


Figure 4: Industrial carbon emissions per wood carbon processed; DL= Dimensional lumber, OSB= oriented strand board. Data from White et al. 2005.

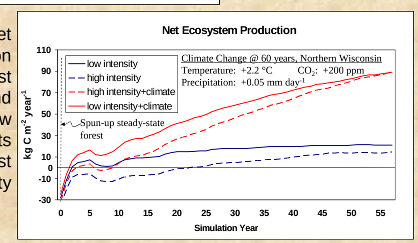


Figure 5. Biological net ecosystem production for different harvest intensities and changing climate. Low intensity represents present day harvest regime. High intensity ≈ double harvest.

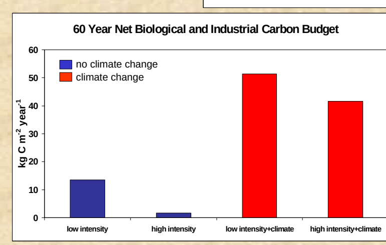


Figure 6. Combined biological and industrial carbon budget for 60-year simulations for the entire CNNF boundary (see Fig. 5). Harvested C for each year were input to LCI model to calculate C emissions.

Observations

- Increased energy efficiency in mill processing and transportation (e.g., distance to mill) could decrease C emissions significantly.
- Moderate (current level) amount of harvesting within the current ownership boundary has a net positive effect on sequestration because young regenerating stands are able to sequester large amounts of C. However, increasing harvest intensity, above some threshold and over a limited area, is likely to have a negative effect on sequestration. Additionally, no harvesting (steady-state forest) has a net sequestration close to 0 (data not shown).

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