Carbon Budgets for Four Forests in Northern California

Kim Gerard Mattson[1], Jianwei Zhang[2], Elijah Pine Cohn[1]

[1]Ecosystems Northwest, Mount Shasta, CA; [2] USDA Forest Service, Pacific Southwest Research Station, Redding, CA

mattson@EcosystemsNorthwest.com

Abstract

Carbon pools and fluxes are being measured in four forests in Northern California. The forests are in the pre-treatment stage where canopies will be experimentally thinned to test the effects of forest canopy on carbon cycling. Using our field measures in a bookkeeping model of carbon pools and annual fluxes, we can develop reasonably accurate estimates of carbon cycles in these four forests.

The four forest types vary considerably in the amounts of carbon stored. For example, above-ground live biomass carbon pool ranges from 104 Mg C ha^{-1} for the 50-year-old Ponderosa Pine conversion stands to more than double that or 256 Mg C $ha^{-1}$for the True Fir Stand found at higher elevations. The Mixed Conifer and the Oak Stand are both mid-way at 140 and 155 Mg C ha^{-1}, respectively. The detrital carbon pools generally follow the above-ground biomass trends but contain more carbon. Approximately 2/3 of the detrital carbon is stored in the mineral soil but significant amounts are also stored in the forest floors and woody debris. Live small roots are relatively small pools of about 5 Mg C ha^{-1} but are active and nearly turnover each year. Dead root pools are generally twice the size of live roots and turnover at half the rate. Woody debris appears to be an important contributor to below-ground carbon. We have derived a humification coefficient where 2/3 of the decomposed carbon leaves the system as CO_2 but more importantly up to 1/3 remains behind to enter the next pool.

Questions / Approach

- How does carbon enter the soil?
- How long does it stay?
- What influences its residence time and loss?
- We are measuring components of carbon cycling and assembling it into a model to answer the above questions.
- These forests will be experimentally thinned and we will try to see how carbon cycling changes.

Methods

We use direct measures as much as possible (litterfall, soil CO_2 efflux, wood decay, harvests, etc.), then make reasonable assumptions for more difficult measures (e.g., annual gross primary production, tree mortality, root decomposition), and finally make some estimates by difference (root mortality or soil carbon turnover). We are able to construct models that balance carbon pools similar to our measures.

Direct Measure of Pools

- Above-ground biomass
- Forest floor
- Woody debris
- Soil organic matter
- Live and Dead roots

Direct Measure of Fluxes

- Litterfall to the forest floor
- Tree mortality to the forest floor
- CO_2 effluxes from soil
- CO_2 effluxes from woody debris
- CO_2 effluxes from roots

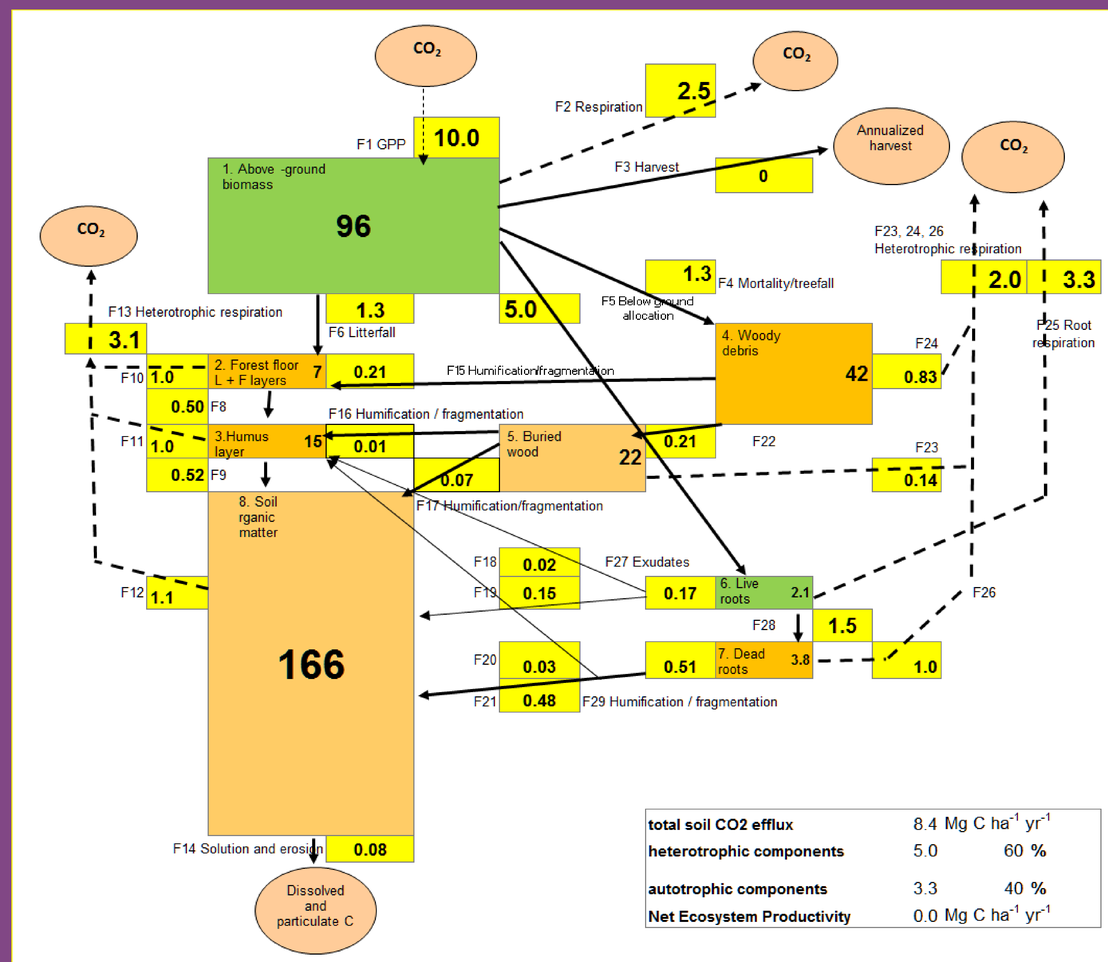
Estimated Fluxes

- Net Primary Production
- Fragmentation/humification of organic matter

The Model

We use a bookkeeping model that moves carbon from one pool to the next using our direct measures, estimates from the literature, and finally differencing to balance the model. By differencing we mean simply calculating otherwise unknown values knowing that carbon is conserved and must balance within the system. The model is run on MS Excel using an annual time-step.

	Measured values				Model values
Mg C ha-1	Mixed Conifer	Oak Forest	Pine Plantation	True Fir Forest	Generic forest
1. Above ground carbon (trees)	140	155	104	256	96
2. Forest floor L+F	8	5	9	11	7
3. Forest floor H	21	6	8	16	15
4. Woody debris	37	12	10	30	42
4a. Standing dead	6	14	2	20	
4b. Stumps	3	0	1	0	
5. Buried wood	19	8	15	16	22
6. Live fine roots	3	5	2	2	2
6a. Live med coarse roots	3	4	4	2	
7. Dead roots	5	5	6	13	4
8. Soil organic carbon 0-30 cm	56	69	69	119	166
8a. Soil organic carbon 30-100 cm	50	94	39	205	
Total organic carbon	349	375	268	690	258
Mg C ha-1 yr-1					
F4. Woody debris inputs	0.5	0.3	0.1	1.1	1.3
F6. Litterfall fine	1.3	1.4	1.0	1.5	1.3
F6a. Litterfall woody debris	0.4	0.5	0.2	0.6	
F18-21. Root inputs					0.7
F25+ F13. CO2 efflux from ff	10.0	11.9	12.7	9.0	8.4



total soil CO2 efflux	8.4	Mg C ha^{-1} yr^{-1}
heterotrophic components	5.0	60 %
autotrophic components	3.3	40 %
Net Ecosystem Productivity	0.0	Mg C ha^{-1} yr^{-1}

Carbon Budget for a Generic Forest in Northern California

Modeled carbon pools (Mg C ha^{-1}) and annual fluxes (Mg C ha^{-1} yr^{-1}). Green or rust-colored boxes represent live or dead pools, respectively. Solid or dashed arrows represent particulate / solution or gasesous fluxes, resp. Yellow boxes are flux rates. The letter "F" with subscript numeral refer to the calculations from a spreadsheet. These are the outputs at year 250 using a donor-controlled annual timestep model parameterized with set of standard assumptions either from the literature or our field bservations. The values were then tuned to produced close to presumed pools and fluxes values. The model parameters are given in Worksheet "Input values." These can be modified for different scenarios.

Interesting findings

- These forests show large variability in carbon storage (e.g., above ground, soil).
- Total carbon storage is large.
- Modeled CO_2 effluxes from the soil are smaller than our measured effluxes.
- Woody debris inputs are important; wood and litterfall inputs to soil are twice the size of root inputs to soil carbon.
- Carbon storage is most sensitive to gross primary production, decomposition rates, and the humification coefficient.
- Can carbon storage be increased in soils?