Carbon Budgets

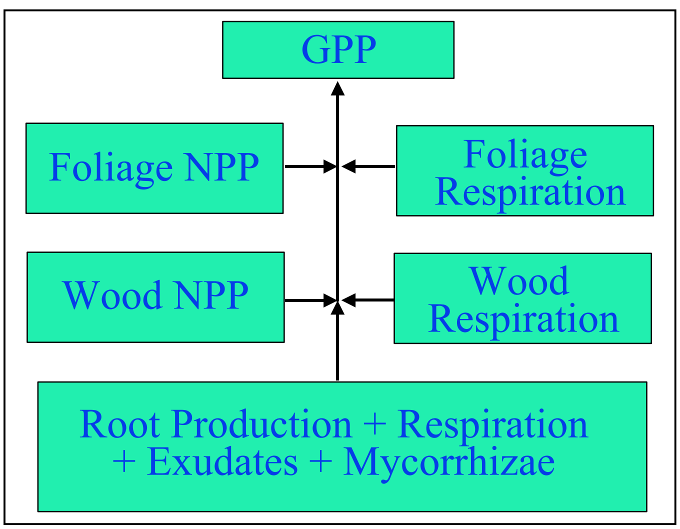
Objectives - You should know:

- Why we are interested in carbon budgets
- The components of a carbon budget, and their relative magnitudes
- How to construct a carbon budget
- What regulates the component processes (photosynthesis, respiration, allocation) at small scales (for example, a leaf on the order of seconds) and larger scales (a forest one the scale of years)
- The sources of uncertainty in constructing carbon budgets
- Differences in C budgets among ecosystems

Why we are interested in carbon budgets

Fixed C is the source of almost all energy for life.
Economic yield of crops depend on C uptake and allocation
Terrestrial vegetation store large amounts of carbon - and fluxes may be sensitive to the environment.

The components of a carbon budget, and their relative magnitudes



Ignoring photorespiration, Pg = NPP (stems + leaves + roots + fruits) + ΔStorage + Respiration (stems + leaves + roots + fruits) + exudates

How to construct a carbon budget

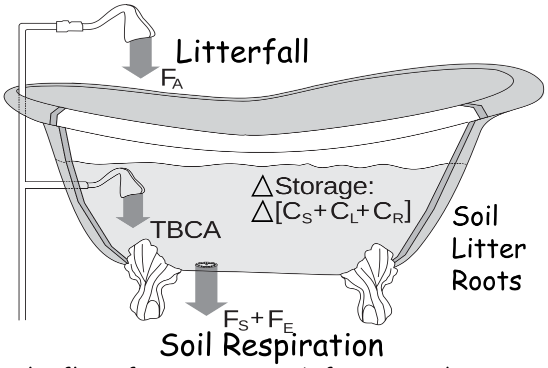
Pg - eddy covariance; models based on climate, leaf area, leaf area distribution, photosynthetic capacity

Summation method:

Aboveground NPP - generally measurements of biomass increment and litterfall

Aboveground Ra - measurements of component parts, or models

How do we Measure? Belowground Allocation



Like measuring the flow of water into a tub from an underwater faucet (= outputs – inputs + storage change)

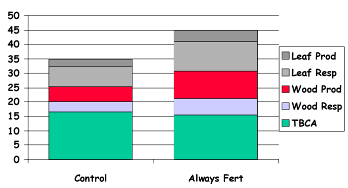
$TBCA = F_S - F_A$ + storage change

TBCA – From carbon balance approach

NPP =~ Ra
Wood NPP – 20%
TBCA: 50%
Ra 50%
Foliage NPP < 10%

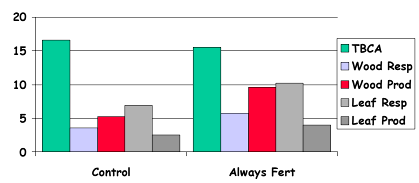
Examples: *Fertilized and unfertilized Eucalyptus, Hawaii*

Fertilization increased growth and respiration (by increasing leaf area and photosynthesis *and* by changing allocation)



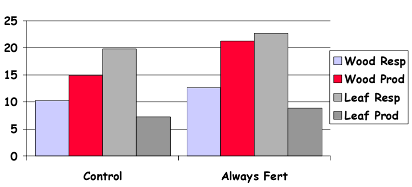
Eucalyptus Carbon Budget (Tons C ha^{-1} yr^{-1})

Same data so you can compare components



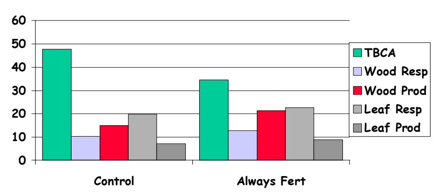
Eucalyptus Carbon Budget (Tons C ha^{-1} yr^{-1})

With continued fertilization, wood was 21% of GPP, instead of 15%--enough for 50 T ha^{-1} more wood in 6 years!



Eucalyptus Carbon Allocation (% of GPP)

Most of the increased allocation to wood came from decreased allocation to belowground



Eucalyptus Carbon Allocation (% of GPP)

What regulates the component processes (photosynthesis, respiration, allocation) at small scales (for example, a leaf on the order of seconds) and larger scales (a forest one the scale of years)

Small scale:

Photosynthesis - think *capacity* and *performance*

Capacity - Enzyme concentration and chlorophyll content, both correlated with canopy N

Performance - light, stomatal opening (humidity, soil water), [CO_2]

Respiration - think *construction* and *maintenance*, but remember that R is likely substrate and sink limited

Construction - amount of tissue and its chemical composition

Maintenance - cellular activity, related to N content.

Allocation - regulated by nutrition, phenology, environment.

Large scale:

Photosynthesis - Energy absorbed (a function of LAI and light), climate, hydraulic regulation

Respiration - about 50% of photosynthesis, but not likely fixed.

Allocation - regulated by nutrition, environment, and genetics.

Always think one scale down (what is the mechanism) and one scale up (does X have an impact on the whole plant? Some other component of the ecosystem?)

The sources of uncertainty in constructing carbon budgets built from measurements

Distribution of samples in space and time

Measurement error in flux rates

Error in biomass estimates

Error in scaling models to canopy, and in time.

Differences in C budgets among ecosystems

Pg in forested ecosystems varies from about 0.5 - 6 kg C $m^{-2\ yr-1}$

Table 2. Component carbon analyses for stands identified by number (Column 1) in Table 1. Data are presented separately for net primary production of all aboveground components (Column 2) and for roots (Column 7). Growth respiration is combined for all aboveground components (R_g). Maintenance respiration (R_m) was subdivided into leaves (Column 4), and stems and branches (Column 5). Estimates of total carbon allocated to roots from growth and maintenance respiration (ΣR) were combined (Column 6). Gross primary production (GPP)[1] (Column 8) and total net primary production (NPP)[2] (Column 9) were derived by summing values from appropriate columns to calculate the ratio of NPP/GPP. All units are in g C m^{-2} $year^{-1}$.

Stand no. (1)	NPP_a (2)	$R_{g(a)}$ (3)	$R_{m(l)}$ (4)	$R_{m(s+b)}$ (5)	ΣR_{root} (6)	NPP_{root} (7)	GPP (8)	NPP (9)	NPP/GPP (10)
1	525	131	97	334	156	156	1399	681	0.49
1a	585	146	108	262	228	228	1557	813	0.52
2	580	145	107	453	190	190	1665	770	0.46
3	875	219	162	653	247	247	2403	1122	0.47
4	255	63	47	278	118	118	879	373	0.42
5	75	19	13	88	84	84	363	159	0.44
6	45	11	8	84	77	77	302	122	0.40
7a	599	149	245	400	511	511	2415	1110	0.46
7b	750	187	291	267	518	518	2531	1268	0.50
7c	1291	323	457	628	370	370	3439	1661	0.48
8	457	114	85	186	202	202	1246	659	0.53
9	690	--370–		210	880	320	2470	1010	0.41

[1] GPP = (2) + (3) + (4) + (5) +(6) + (7).
[2] NPP = (2) + (7).