Belowground Carbon Protocols

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What is belowground Carbon?

- Coarse and fine roots

- Soil Carbon
  - Organic carbon within mineral soils
    - Also, organic soils (mucks, peats)
    - And, Spodosols (organic accumulations at depth)
  - Forest Floor (i.e., the soil O horizon)
  - Coarse woody debris

Belowground root biomass

Longleaf pine stump 14” (35 cm) diameter at a depth of 10 ft (3 m) in the ground. Stump at ground line 24” (61 cm) diameter. George County, MS.

USFS Photo, April 1927

Belowground Soil Carbon

Coarse Woody Debris

Forest Floor (O Horizon)

Mineral Soil (A,E,B Horizon)

Lower Coastal Plain Spodosol

Organic rich spodic horizon (Bh designation) at 12” (30 cm) depth.

Quantifying Belowground C

- Difficult for roots and soil due to visual impairment
  - (i.e., its belowground)

- Difficult for soil carbon change because there is already a large background

Georgia Carbon Sequestration Registry

- Includes
  - Coarse roots
    - Fine roots excluded
  - Mineral soil organic carbon
    - Mineral soil includes organic soils (i.e., Histosol)
    - Excludes forest floor and coarse woody debris

- Tier I and II
  - Aboveground: With/Without Reliable Inventory
  - Belowground: Assume no inventories exist, Tier I and II distinguish between levels of complexity and cost in making estimates.

Quantifying Coarse Root C

- Tier I approach
  - Studies of tree growth physiology indicate a relatively constant ratio between above and belowground tree biomass
    - (i.e., shoot:root ratio)
  - Ratio is ~4:1 or 20% of total tree biomass is belowground

Coarse Root C

– As such

Belowground coarse root carbon (C_b) =

Aboveground merchantable C (C_a) x 0.25

$C_b = C_a \times 0.25$

And $C_a + C_b$ = total merchantable tree C

Coarse Root C

- Participants in the GCSR will be expected to utilize the data generated from the aboveground accounting scheme for belowground estimation.

- Thus, aboveground C registration is required for belowground coarse root C registration.

Coarse Root C

- Tier II
  - Directly stimating belowground coarse root C is extremely difficult, costly, has high uncertainty, and lacks a standard procedure.
  - No direct measures will be accepted

Coarse Root C

- Verification
  - Procedures outlined for aboveground forest carbon will be utilized for verification of belowground C
  - No direct measures will be required for verificaiton

Mineral Soil Carbon

- There is much interest and optimism in the ability of forest soils to sequester C
- This derives from
  - The large amount of soil C in forest ecosystems, and
  - The large losses (~40%) of surface soil carbon loss during conversion to agriculture that, theoretically, should be recoverable

Forest Carbon Contents

Component	Tulip Poplar 50-yr-old TN	Loblolly Pine 34-yr-old SC
	Mg ha^{-1}	
Tree C	80	140
Forest Floor C	3	35
Soil C	80	84

Mineral Soil C loss during forest conversion to agriculture

	C concentration	Soil mass	C content	
	% change of g-C/kg soil	% change of g-soil/m^2	% change of g-C/m^2	
A horizons	-43.3	-0.6	-42.7	n=7*
A and B horizons	-36.8	-3.6	-38.1	n=7*
Entire Solum	-14.7	-9.8	-30.5	n=5
All data	-25.9	+0.2	-27.2	n=18

Davidson and Ackerman

Mineral Soil Carbon

- Despite this optimism there is uncertainty about the quantitative rate of soil carbon accumulation under afforestation or forest management

- Regardless of this uncertainty there is general agreement that during afforestation (i.e., site planted to trees after >10 yr of agriculture) soils will sequester C

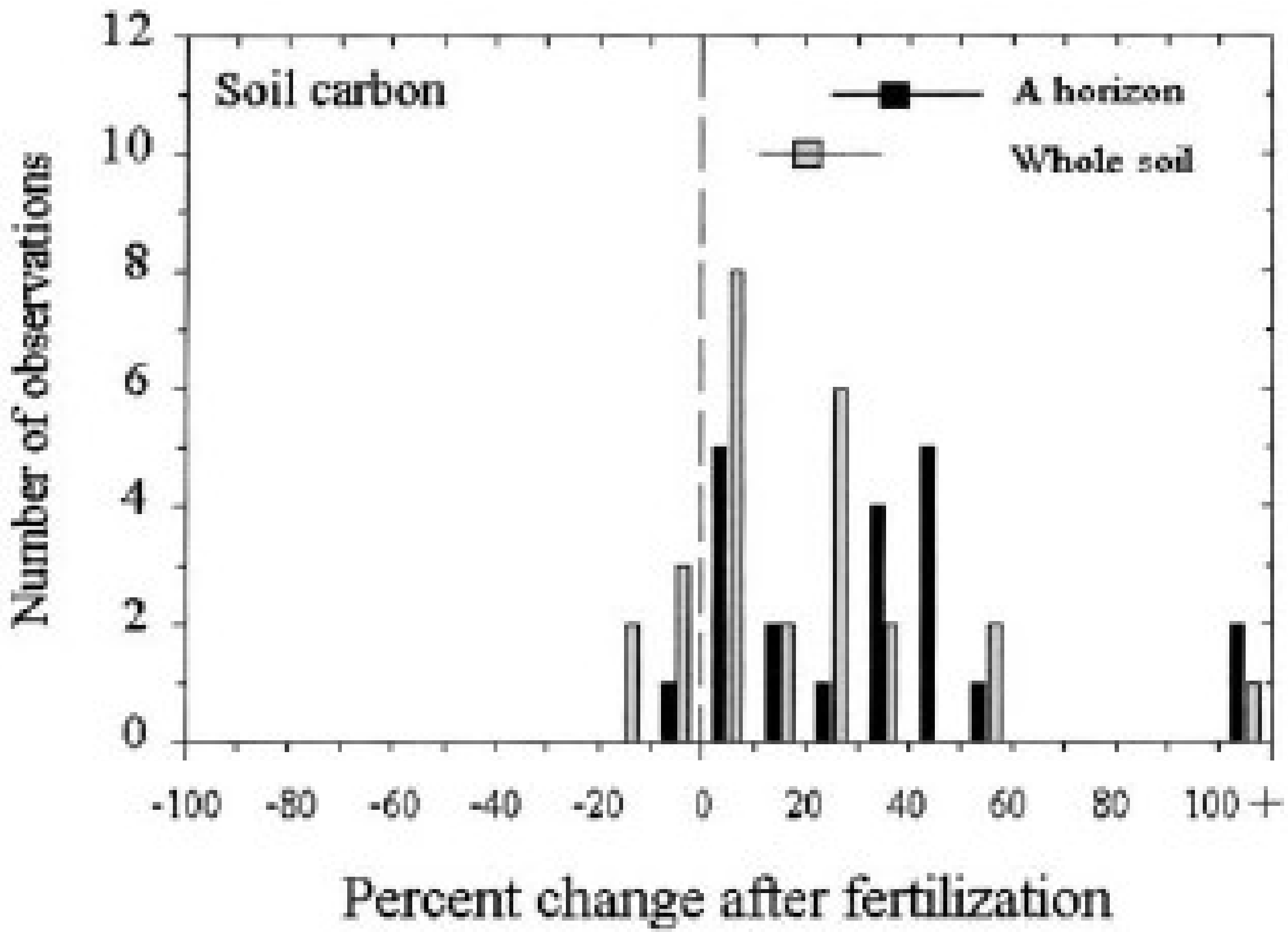
- Similarly, there is general agreement that forest fertilization will lead to increased soil C sequestration

Mineral Soil C gain during agriculture conversion to forest

	Years since Ag	Avg rate of change kg ha^{-1} yr^{-1}
Old field to pine to hardwood	200	24
	120-180	45
Old field to natural pine	40-60	29
	50	282
	50-70	118
	110	59
Old field to planted pine	50	248
	70	255
	40	36
Average rate of soil C gain		122

Post and Kwon

Mineral Soil C gain with forest fertilization



Johnson and Curtis

Quantifying Soil C

- Tier I approach
  - Landowners that are afforesting fields that have spent >10 yr in conventional agriculture can use look-up tables to register soil C sequestration
  - To use these tables a land owner would look up the appropriate stand type and age and multiply by the annual rate by the number of years.

Quantifying Soil C

- For example, if a landowner has a 5-yr-old loblolly pine plantation and they want to estimate potential sequestration through age 15

- Look-up table 3.3.1

Table 3.3.1. Regional estimates of soil C accumulation rates for loblolly-shortleaf pine stands with afforestation of land.

Age	Accumulation rate Mg/acre
0-5	0.02
6-10	0.04
11-15	0.09
16-20	0.09
21-25	0.13
26-30	0.13
31-35	0.13
36-40	0.13
41-45	0.13
45-50	0.13

Quantifying Soil C

- For this example, the landowner would use the 0-5 age rate for 1 yr, the 6-10 age rate for 5 yr, and the 11-15 age rate for 4 yr
  - Soil C sequestration per acre from age 5 to 15
    = (1x0.02 Mg-C/ac) + (5x0.04 Mg-C/ac) + (4x0.09 Mg-C/ac)
    =0.62 Mg-C/ac

- Then multiply by the number of acres

Quantifying Soil C

- To utilize tier I, land owners must demonstrate >10 yr of agricultural activity (i.e., tax records, aerial photos) and the appropriate forest type.

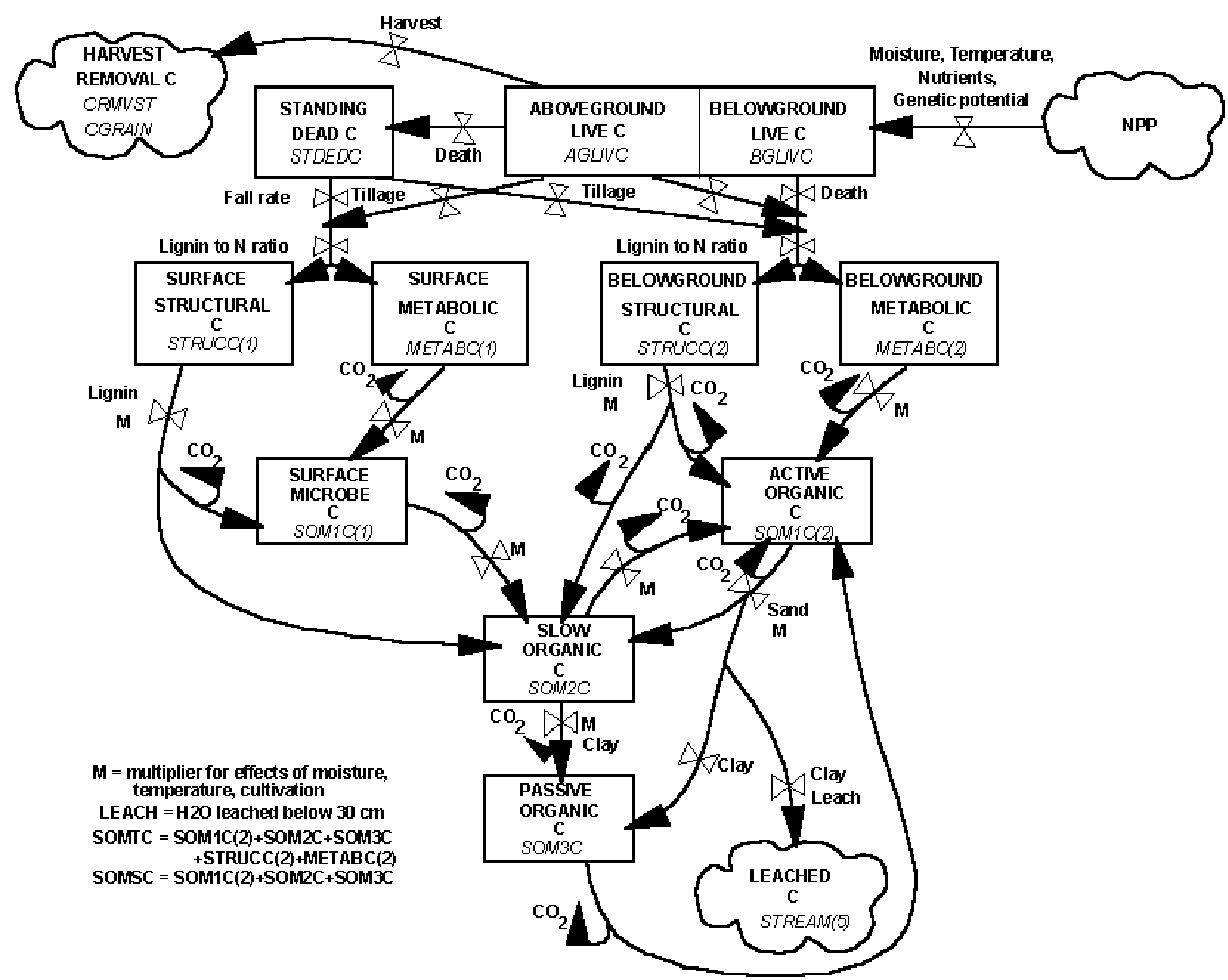
Quantifying Soil C

- Tier II
  - Landowners may believe their management activities have the potential to sequester soil C at rates exceeding those in tier I tables or may believe soil C sequestration is likely in scenarios other than afforestation

  - The registry will accept other estimations of soil C sequestration (i.e., model estimations) but will require on the ground inventories for initial and contract termination C contents.

There is no preferred model

A diagramatic representation of the Century Model is below



Soil C Inventory

- Soil C inventory can be paired with aboveground merchantable tree C inventory but will require a separate estimate of variance (and potentially a different sampling intensity) to achieve a similar ±20% estimated Allowable Error

- The table reports the average coefficient of variation for C content estimates of different forest components

	Coefficient of Variation	# of studies
	%	
Aboveground	15	18
Forest Floor	39	23
Coarse Woody Debris	49	7
Soil	24	17

Sample numbers required to estimate a 10 or 20% change in any forest C pool with a 95% level of confidence given a 10 to 50% CV in the estimation of that pool

Coefficient of Variation	Probability of detecting change	
	95%	
	Percent Change	
	10%	20%
10	4	2
30	36	9
50	100	25

Quantifying Soil C

- Two Methodological References from other protocols are provided in your packet

- It is assumed at present that the cost of soil C inventory greatly exceeds the income potential from C trading, if this situation changes so to will the GCSR protocols for soil C

A final thought…

Attempting to hoard as much organic matter as possible in the soil, like a miser hoarding gold, is not the correct answer. Organic matter functions mainly as it is decayed and destroyed. Its value lies in its dynamic nature.

William Albrecht (1938)

.. soil organic matter is far more than a potential tank for impounding excess CO_2; it is a relentless flow of C atoms, through a myriad of streams—some fast, some slow—wending their way through the ecosystem, driving biotic processes along the way.

H.H. Janzen (2006)

Citations:

- Davidson, EA and I Ackerman. 1993. Changes in soil carbon inventories following cultivation of previously untilled soils. Biogeochemistry 20:161-193.
- Johnson, DW and PS Curtis. 2001. Effects of forest management on soil C and N storage: meta analysis. Forest Ecology and Management 140:227-238.
- Post, WM and KC Kwon. 2000. Soil carbon sequestration and land-use change: Processes and potential. Global Change Biology 6:317-328.