Above-Ground Tree Carbon Estimation Protocols Georgia, USA

Bruce Borders
Warnell School of Forestry and Natural Resources

Carbon Sequestration Certification
June 5-6, 2007
UGA – Georgia Center for Continuing Education

Above Ground Protocol

- Recall - Estimation of carbon stored in stem wood is a timber inventory/ growth and yield exercise
- We need to obtain an estimate of the volume or weight of stem wood and then convert this estimate to tons of carbon
- NOTE – approximately one-half of dry wood weight is carbon, hence if we can estimate dry weight of stem wood we can easily convert it to weight of carbon by multiplying by ½

Above Ground Protocol

We can use the following relationship to convert cubic volume of green wood to carbon weight in wood

$$SG_B = \frac{W_D / V_G}{D_{Water}}$$

SG_B = basic specific gravity

W_D = dry weight of wood

V_G = green volume of wood

D_{Water} = density of water = 62.4 lbs/ ft^3

Above Ground Protocol

$$W_D = (SG_B)(D_{Water})(V_G) = 62.4(SG_B)(V_G)$$

$$W_C = (0.5)W_D$$

Example – we have 1000 cubic feet of loblolly pine wood per acre (green volume inside bark - V_G)

Average SG_B for loblolly pine is about 0.47, therefore we can estimate dry weight of wood as

W_D = 62.4*0.47*1000 = 29,328 lbs

W_C = 14,664 lbs or about 7.3 tons

Basic Specific Gravity by Species/ Group

Species/Species Group	Specific Gravity
Loblolly pine (Pinus taeda L.)	0.47
Slash pine (Pinus elliottii)	0.54
Longleaf pine (Pinus palustris)	0.54
Other pines (Pinus spp.)	0.46
Soft Hardwoods[1]	0.46
Hard Hardwoods[2]	0.58

Above Ground Protocol

- Note – we can estimate dry weight of wood from green weight of wood as:

$$W_D = (1 - MC_G) * W_G$$

Where:

W_D = dry weight of wood

W_G = green weight of wood

MC_G = moisture content of wood defined as:

$$MC_G = (W_G - W_D) / W_G$$

Above Ground Protocol

- Suppose we have estimated 75 standing green tons of wood in a loblolly pine stand
- From the work of Clark and Daniels (2000) we can obtain an estimate of MC_G to be 53.5% or 0.535
- Thus, we can estimate standing dry tons to be:

$$W_D = (1 - MC_G) * W_G$$
$$= (1 - 0.535) * 75 = 34.875 \text{ tons}$$

- Of course, carbon is then estimated to be approximately 17.4 tons (1/ 2 of W_D)

Above Ground Protocol

- Clark, A and R. Daniels. 2000. Estimating moisture content of tree-length roundwood. TAPPI – Pulping/ Process & Product Quality Conference Proceedings.

Above Ground Protocol

- Recall, to determine standing tons of carbon in a timber stand we can follow normal cruising practices to obtain one of the following:
  - Inside bark green volume (i.b. cubic foot volume equation - V_G)
  - Inside bark green weight (i.b. green weight equation - W_G) in conjunction with a legitimate estimate of moisture content
  - Inside bark dry weight (i.b. dry weight equation - W_D)
- Make the appropriate calculation to convert the available estimate to carbon weight

Entities With Reliable Inventory

- Stand level probability samples available with estimates of standing tree volume or weight
  - Conducted by registered forester
  - < 10 years old
  - Sample precision <= 15% estimated Allowable Error (AE)
  - Use conversion procedures to obtain estimates of carbon weight

Individual Tree Volume/ Weight Equation Examples

- Harrison, M. and B. Borders. 1996. Yield prediction and growth projection for site-prepared loblolly pine plantations in the Carolinas, Georgia, Alabama and Florida. PMRC Technical Report 1996-1. The University of Georgia. 59 pp.
- Pienaar, L.V., et al. 1996. Yield prediction for mechanically site-prepared slash pine plantations in the Southeastern Coastal Plain. PMRC Technical Report 1996-3. The University of Georgia. 57 pp.

Individual Tree Volume/ Weight Equation Examples – Cutover Slash Pine

$$VOB_m = .00456D^{2.0726}H^{.8114} - .00265(D_m^{3.8846}/D^{1.8846})(H - 4.5) \quad (1.1)$$

$$VIB_m = .001735\,D^{2.0586}H^{1.0026} - .00200\,(D_m^{3.6994}/D^{1.6994})(H - 4.5) \quad (1.4)$$

Where:

VOB = cubic foot volume outside bark (ob)

VIB = cubic foot volume inside bark (ib)

D = tree DBH (inches)

H = total tree height (feet)

Dm = merchantable top diameter (ob)

Individual Tree Volume/ Weight Equation Examples – Cutover Slash Pine

$$GWIB_m = .1047D^{2.0544} H^{1.0224} - .0892 (D_m^{3.6729} / D^{1.5156}) (H - 4.5) \quad (1.8)$$

$$DWIB_m = .0373 D^{1.8670} H^{1.2070} - .0458 (D_m^{3.9416} / D^{1.7984}) (H - 4.5) \quad (1.9)$$

$$DWIB_m = .0383 D^{1.8831} H^{1.1340} A^{.0795} - .0454 (D_m^{3.9375}/D^{1.7864})(H - 4.5) \quad (1.10)$$

Where:

GWIB = green weight inside bark (ib) (lbs)

DWIB = dry weight inside bark (ib) (lbs)

D = tree DBH (inches)

H = total tree height (feet)

Dm = merchantable top diameter (ob)

A = stem age

Individual Tree Volume/ Weight Equation Examples – Cutover Slash Pine

Illustrative Example

Use of the volume, taper and weight equations are illustrated below for a tree with D = 10 inches and H = 60 ft. The equation used to obtain the estimate is given in parentheses.

Volume:

$VOB_0 = 14.94\ ft^3$	(1.1)	$VIB_0 = 12.04\ ft^3$	(1.4)
$VOB_0 = 14.52\ ft^3$	(1.1)	$VIB_4 = 11.67\ ft^3$	(1.4)
$VOB_8 = 8.76\ ft^3$	(1.1)	$VIB_8 = 7.18\ ft^3$	(1.4)

NOTE – VOB = 14.52 ft^3 is for a 4 inch top not 0 inch top.

Individual Tree Volume/ Weight Equation Examples – Cutover Slash Pine

$$W_D = (SG_B)(D_{Water})(V_G) = 62.4(SG_B)(V_G)$$

For slash pine average basic specific gravity is 0.54

So for VIB_4 = 11.67 ft3 we can estimate dry weight of wood as:

W_D = 62.4(0.54)(11.67) = 393.2 pounds

Hence our estimate of sequestered carbon is 0.5(393.2) = 196.6 pounds

Individual Tree Volume/ Weight Equation Examples – Cutover Slash Pine

Green Weight:

$GWOB_0$ = 875.6 lbs (1.7)	$GWIB_0$ = 780.4 lbs (1.8)
$GWOB_4$ = 846.8 lbs (1.7)	$GWIB_4$ = 755.8 lbs (1.8)
$GWOB_8$ = 515.4 lbs (1.7)	$GWIB_8$ = 467.1 lbs (1.8)

Recall - $W_D = (1 – MC_G)* W_G$

If we assume average MC_G for slash pine is about 50% (0.50) we find

For $GWIB_4$ we find W_D = (1-0.5)*(755.8) = 377.9 lbs and Carbon = 189 lbs

Individual Tree Volume/ Weight Equation Examples – Cutover Slash Pine

Dry Weight:

	Age 15	Age 25
$DWIB_0$ = 384.5 lbs (1.9)	376.9 lbs (1.10)	392.5 lbs (1.10)
$DWIB_4$ = 374.9 lbs (1.9)	367.2 lbs (1.10)	382.8 lbs (1.10)
$DWIB_8$ = 236.6 lbs (1.9)	228.7 lbs (1.10)	244.3 lbs (1.10)

Clearly, it is very straight forward to estimate carbon if you are calculating dry weight of wood – simply multiply by 0.5 to estimate carbon to 4 inch top to be 191 lbs

Entities With Reliable Inventory
Carbon Tables

- Two general approaches (use of Carbon Tables and use of Growth and Yield (G & Y) software with appropriate conversions)
  - Carbon tables – find appropriate carbon table for stand type/ age of inventory – determine average annual carbon accumulation from table for ages between inventory age and start of carbon contract – add the carbon accumulation from the table to the inventory estimate
  - Determine carbon accumulation during contract period and add this to the carbon present at start of contract period to obtain final standing carbon

Entities With Reliable Inventory
Carbon Tables

- Carbon Tables developed for major stand types found in Georgia
- Each table presents tons of carbon by age and product (pulp DBH <= 11.5” plus 15% degrade from stems with DBH > 11.5” and sawtimber DBH > 11.5” minus 15% degrade to pulp)

Entities With Reliable Inventory Carbon Tables

- Many factors impact growth and yield of timber stands:
  - Species/Species Mix
  - Site quality (site index)
  - Stand origin (planted cutover, planted old field, natural regeneration)
  - Stand density (trees/ acre, basal area/ acre)
  - Thinning condition (unthinned, one or more thins)
  - Management Intensity
  - Level of Genetic Improvement (if planted stand)

Entities With Reliable Inventory Carbon Tables

- Tables developed for all combinations of the following categories:
  - Species – Loblolly pine, Slash pine, Longleaf pine, Hardwood
  - Origin – Planted cutover site, Planted ag field (CRP), Natural regeneration
  - Site Index Class (base age 25 for planted stands, base age 50 for natural stands)
    - Low, Medium, High (classes vary by species – see protocol)

Entities With Reliable Inventory
Carbon Tables

- Tables developed for all combinations of the following categories:
  - Stand density at planting – Low (<=575 trees/ acre) and High (> 575 trees/ acre)
  - Stand density for natural regeneration – Low and High (class limits vary by species – no density classes for hardwood stands)
  - Thin History – Unthinned or Thinned

Entities With Reliable Inventory Carbon Tables

- Tables developed for all combinations of the following categories:
  - Management Intensity (planted stands only)
    - Extensive
      - No vegetation control via herbicides
      - No fertilization
    - Intensive
      - Successful woody vegetation control at site preparation
      - Herbaceous weed control in year of planting
      - Fertilization following thinning operations

Entities With Reliable Inventory
Carbon Tables

- Tables developed for all combinations of the following categories:
  - Level of Genetic Improvement (planted stands only)
    - Unimproved (if unknown stands established < 1986)
    - First generation improvement (if unknown stands established between 1986 and 1999)
    - Second generation improvement (if unknown stands established 2000 forward)

Loblolly	Planted	High	Low	Int	UI	LCP	CC
Age	PWCarbon	STCarbon	PWThin				
5	1.44	0	0				
6	3.04	0	0				
7	4.71	0	0				
8	6.48	0	0				
9	8.27	0	0				
10	10.1	0	0				

Header record (left to right):

Species = Loblolly pine

Stand origin = Planted

Site Index Class = High

Stand Density Class = Low

Management Intensity = Int (intensive) or Ext (extensive)

Genetic Improvement = UI (unimproved) or 1G (1st generation) or 2G (2nd generation)

Physiographic Region = LCP (lower coastal plain), PID (piedmont) or ALL (no regional differences available)

Table type = CC (clearcut table – no previous thinning), T14, T15, etc.. (table for stands thinned at age 14, age 15, etc.)

Loblolly	Planted	High	Low	Int	UI	LCP	CC
Age	PWCarbon	STCarbon	PWThin				
5	1.44	0	0				
6	3.04	0	0				
7	4.71	0	0				
8	6.48	0	0				
9	8.27	0	0				
10	10.1	0	0				
11	11.94	0	0				
12	13.71	0.08	0				
13	15.44	0.18	0				
14	17.09	0.35	8.14				
15	18.62	0.62	9.4				
16	20.03	0.98	10.64				
17	21.31	1.45	11.82				
18	22.44	2.03	12.97				
19	23.41	2.73	14.1				
20	24.25	3.56	15.28				
21	24.92	4.49	16.4				
22	25.46	5.52	17.47				
23	25.85	6.66	0				
24	26.12	7.88	0				
25	26.26	9.2	0				
26	26.29	10.59	0				
27	26.22	12.04	0				
28	26.06	13.54	0				
29	25.81	15.09	0				
30	25.5	16.66	0				
31	25.13	18.26	0				
32	24.72	19.89	0				
33	24.27	21.51	0				
34	23.79	23.12	0				
35	23.3	24.73	0				
36	22.79	26.31	0				
37	22.28	27.86	0				
38	21.77	29.39	0				
39	21.27	30.88	0				
40	20.78	32.37	0				
41	20.31	33.79	0				
42	19.86	35.17	0				
43	19.43	36.5	0				
44	19	37.81	0				
45	18.59	39.08	0				
46	18.21	40.3	0				
47	17.86	41.47	0				
48	17.54	42.59	0				
49	17.26	43.71	0				

Planted Loblolly, High Site, Low Density,

Intensive Management, Unimproved Genetics,

Lower Coastal Plain, Clearcut table (i.e. no past thinning)

Entities With Reliable Inventory
Carbon Estimation – Use of Tables

- Let's assume we have a cruise from a 15 year old slash pine plantation that was carried out 4 years ago. From the cruise work up we estimate that there were 8 tons/ acre of pulpwood carbon (stems with DBH <=11.5" to 3" top dob). Note, we need to determine carbon for current year.
- Further, we are negotiating for a carbon offset contract that will be in effect for the next 10 years – therefore, we need to determine how much carbon will be accumulated over this 10 year period

Entities With Reliable Inventory
Carbon Estimation – Use of Tables

- From available data, we also determine that
  - SI_{25} = 60 area (i.e. medium site quality),
  - The stand was planted with fewer than 575 tpa (i.e. low density)
  - 1st Generation planting stock was used
  - The stand was managed extensively (i.e. no herbicide treatment, no fertilization) and it has never been thinned.
  - To keep things simple, we will assume that no thinning will occur during the 10 year contract period.

Slash	Planted	Med	Low	Ext	1G	LCP	CC
Age	PWCarbon	STCarbon	PWThin				
5	0	0	0				
6	0.02	0	0				
7	0.18	0	0				
8	0.6	0	0				
9	1.23	0	0				
10	2.06	0	0				
11	3.12	0	0				
12	4.04	0	0				
13	4.97	0	0				
14	5.91	0	0				
15	6.85	0	0				
16	7.79	0	0				
17	8.73	0	0.32				
18	9.66	0	0.77				
19	10.59	0	1.25				
20	11.5	0	1.71				
21	12.38	0	2.17				
22	13.15	0.11	2.66				
23	13.89	0.2	0				
24	14.57	0.34	0				
25	15.17	0.54	0				
26	15.68	0.78	0				
27	16.1	1.07	0				
28	16.45	1.4	0				
29	16.72	1.8	0				
30	16.91	2.23	0				
31	17.04	2.69	0				
32	17.11	3.17	0				
33	17.12	3.68	0				
34	17.1	4.22	0				
35	17.03	4.75	0				
36	16.93	5.29	0				
37	16.8	5.82	0				
38	16.65	6.35	0				
39	16.49	6.89	0				
40	16.31	7.41	0				

PW Carbon at age 15 = 6.85 tons/ acre

PW Carbon at age 19 = 10.59 tons/ acre

PW Carbon change over 4 years = 3.74 tons/acre

Therefore, we estimate that our stand currently has 8 + 3.74 = 11.74 tons/acre

Slash	Planted	Med	Low	Ext	1G	LCP	CC
Age	PWCarbon	STCarbon	PWThin				
5	0	0	0				
6	0.02	0	0				
7	0.18	0	0				
8	0.6	0	0				
9	1.23	0	0				
10	2.06	0	0				
11	3.12	0	0				
12	4.04	0	0				
13	4.97	0	0				
14	5.91	0	0				
15	6.85	0	0				
16	7.79	0	0				
17	8.73	0	0.32				
18	9.66	0	0.77				
19	10.59	0	1.25				
20	11.5	0	1.71				
21	12.38	0	2.17				
22	13.15	0.11	2.66				
23	13.89	0.2	0				
24	14.57	0.34	0				
25	15.17	0.54	0				
26	15.68	0.78	0				
27	16.1	1.07	0				
28	16.45	1.4	0				
29	16.72	1.8	0				
30	16.91	2.23	0				
31	17.04	2.69	0				
32	17.11	3.17	0				
33	17.12	3.68	0				
34	17.1	4.22	0				
35	17.03	4.75	0				
36	16.93	5.29	0				
37	16.8	5.82	0				
38	16.65	6.35	0				
39	16.49	6.89	0				
40	16.31	7.41	0				

At age 19 our stand has 8 + 3.74 = 11.74 tons/acre of carbon

During the contract period, the stand will move from age 19 to age 29 years.

PW Carbon at age 19 = 10.59 tons/acre

ST Carbon at age 19 = 0 tons/acre

PW Carbon at age 29 = 16.72 tons/acre

ST Carbon at age 29 = 1.8 tons/acre

PW Carbon Change over 10 years = 6.13 tons/ac

ST Carbon Change over 10 years = 1.8 tons/ac

At end of contract we have 11.74 + 6.13 = 17.9 tons/ac PW Carbon and 1.8 tons/ac ST Carbon

Entities With Reliable Inventory
Carbon Estimation – Use of G & Y Software

- Now, I will illustrate use of G & Y software – specifically, I will use SiMS 2006 (the system used to develop the Tables discussed above – however any generally recognized growth and yield system should be adequate)
  - Based on our cruise at age 15 we know the following:
    - Age = 15, SI = 60 feet
    - TPA @ 15 = 430, 1st Generation Stock was Planted
    - Extensive Management (no herbicide, no fertilization)
  - This information is entered into SiMS 2006 and an extensive management scenario is simulated assuming no thinning

Entities With Reliable Inventory
Carbon Estimation – Use of G & Y Software

SiMS 2006 Output Yield = Cubic Feet of Wood

Age	Yield	Yield		Dry Wt PW	Dry Wt ST	PW Carbon	ST Carbon
	Pulpwood	Sawtimber					
15	1,096.9	0.0		36961.1	0.0	9.2	0.0
16	1,244.5	0.0		41934.7	0.0	10.5	0.0
17	1,388.2	0.0		46776.8	0.0	11.7	0.0
18	1,527.3	0.0		51463.9	0.0	12.9	0.0
19	1,663.8	0.0		56063.4	0.0	14.0	0.0
20	1,794.0	0.0		60450.6	0.0	15.1	0.0
21	1,918.2	0.0		64635.7	0.0	16.2	0.0
22	2,022.9	15.6		68163.6	525.7	17.0	0.1
23	2,122.0	29.2		71502.9	983.9	17.9	0.2
24	2,208.0	49.3		74400.8	1661.2	18.6	0.4
25	2,280.3	79.5		76837.0	2678.8	19.2	0.7
26	2,338.0	116.2		78781.2	3915.5	19.7	1.0
27	2,381.4	160.8		80243.7	5418.3	20.1	1.4
28	2,411.2	212.7		81247.8	7167.1	20.3	1.8
29	2,429.0	274.4		81847.6	9246.2	20.5	2.3
30	2,435.1	339.8		82053.1	11449.9	20.5	2.9
31	2,431.3	409.8		81925.1	13808.6	20.5	3.5
32	2,418.9	483.2		81507.3	16281.9	20.4	4.1
33	2,399.9	562.4		80867.0	18950.6	20.2	4.7
34	2,374.5	640.8		80011.2	21592.4	20.0	5.4
35	2,344.4	719.9		78996.9	24257.8	19.7	6.1
36	2,310.5	798.9		77854.6	26919.7	19.5	6.7
37	2,273.8	877.1		76618.0	29554.8	19.2	7.4
38	2,235.6	957.5		75330.8	32263.9	18.8	8.1
39	2,195.6	1,033.4		73982.9	34821.4	18.5	8.7
40	2,154.9	1,107.4		72611.5	37315.0	18.2	9.3

Entities With Reliable Inventory
Carbon Estimation – Use of G & Y Software

Recall – our inventory estimate at age 15 is 8 tons/ acre PW Carbon

The PW C accumulation from age 15 to age 19 is 4.8 tons/ acre – add this amount to find PW C at start of contract to be 12.8 tons/acre

PW C from age 19 to age 29 changes by 6.5 tons – add this to 12.8 to determine we expect 19.3 tons PW C at age 29 and we expect 2.3 tons ST C at age 29

Of course, we can simply use the accumulation from age 19 to age 29 directly from the simulation output as the expected Carbon accumulation by product during the contract period – we go through the process above if we need to have best estimate of total standing carbon at a given age

Entities With Reliable Inventory
Carbon Estimation – Verification

Verification is relatively straight forward – use the inventory as updated to the start of the carbon contract year

Carry out another inventory at end of the carbon contract year –

Take the difference between inventory at end of contract (C_2) and at start of contract (C_1) to obtain an estimate of the gain – Assuming both inventories are independent the estimate of gain is simply

Gain = $C_2 - C_1$

Entities With Reliable Inventory
Carbon Estimation – Verification

Variance of the Gain is = $(\text{Std Error 1})^2 + (\text{Std Error 2})^2$

Std Error of Gain = sqrt(Variance of Gain)

NOTE – C_1 may be the result of adding a tabled amount of C to the inventory C from several years ago – you will know the standard error of C at inventory but not the standard error associated with the modeled gain (this number can not be calculated) – therefore an adjustment to the C standard error at inventory should be made by multiplying by a factor of 1.2 (i.e. an arbitrary increase in standard error of 20%) – this factor may be modified based on future study of this issue

Entities Without Reliable Inventory

- Registered forester examines the stand and identifies
  - Major species
  - Stand origin (planted cutover site, planted ag. field, natural)
  - Stand age
  - Site quality class
  - Stand density (low, high)
  - Thinning condition (pine stands only)
  - Management intensity (planted pine only)
  - Level of genetic improvement (planted pine only)

Entities Without Reliable Inventory

- Use appropriate carbon table to assess carbon at start of contract period
- Use appropriate carbon table to assess carbon at end of contract period
  - Take the difference between end of period and start of period (on a stand by stand basis) and determine the carbon accumulation over the contract period
- NOTE – it should be understood by both buyer and seller that carbon accumulation estimates determined from regional tables will not be as accurate/ precise as those starting from inventory data – nor from growth and yield systems that are set up to more closely represent the stand(s) of interest.

Entities Without Reliable Inventory

- Example – you have a Loblolly pine plantation planted in 1995 in the Piedmont of Georgia
- Based on examination of the stand, discussion with the landowner and examination of available records the following information is determined
  - Site Index Class = Medium
  - Initial Density Class = Low
  - Management = Extensive (no use of herbicide or fertilizer)
  - Genetic Improvement is unknown so use the default for this time period = 1G
  - No thin history

Loblolly	Planted	Med	Low	Ext	1G	PID	CC
Age	PWCarbon	STCarbon	PWThin				
5	0	0	0				
6	0.2	0	0				
7	1.04	0	0				
8	2.14	0	0				
9	3.36	0	0				
10	4.51	0	0				
11	5.68	0	0				
12	6.88	0	0				
13	8.13	0	0				
14	9.42	0	1.96				
15	10.75	0	2.77				
16	12.12	0	3.61				
17	13.51	0	4.5				
18	14.93	0	5.43				
19	16.37	0	6.37				
20	17.82	0	7.31				
21	19.27	0	8.28				
22	20.64	0.08	9.32				
23	21.98	0.2	0				
24	23.21	0.41	0				
25	24.3	0.74	0				
26	25.21	1.26	0				
27	25.92	1.95	0				
28	26.42	2.85	0				
29	26.69	3.95	0				
30	26.75	5.23	0				
31	26.63	6.71	0				
32	26.33	8.34	0				
33	25.88	10.09	0				
34	25.31	11.93	0				
35	24.65	13.85	0				
36	23.93	15.83	0				
37	23.16	17.83	0				
38	22.37	19.83	0				
39	21.57	21.82	0				
40	20.77	23.78	0				

Land owner will enter into a contract for 10 years

Current C (age 12) = 6.88 tons Pulpwood

Future C (age 22) = 20.64 tons Pulpwood, 0.1 tons Sawtimber

Gain over 10 years = 13.86 (14 tons)

Entities Without Reliable Inventory

- Example – you have a Loblolly pine plantation planted in 1988 in the LCP of Georgia
- Based on examination of the stand, discussion with the landowner and examination of available records the following information is determined
  - Site Index Class = High
  - Initial Density Class = High
  - Management = Intensive Genetic Improvement is unknown so use the default for this time period = 1G
  - Thinned at Age 17

Loblolly	Planted	High	High	Int	1G	LCP	T17
Age	PWCarbon	STCarbon					
18	12.08	1.39					
19	12.85	2.29					
20	12.97	4.09					
21	12.99	5.76					
22	13.02	7.49					
23	12.84	9.48					
24	12.61	11.41					
25	12.38	13.34					
26	12.16	15.27					
27	11.96	17.15					
28	11.85	18.88					
29	11.82	20.49					
30	11.79	22.11					
31	11.75	23.68					
32	11.72	25.23					
33	11.69	26.75					
34	11.64	28.25					
35	11.6	29.67					
36	11.56	31.07					
37	11.53	32.46					
38	11.51	33.82					
39	11.53	35.06					
40	11.59	36.22					

Land owner will enter into a contract for 15 years

Current C (age 19) = 12.9 tons Pulpwood, 2.3 tons Sawtimber

Future C (age 34) = 11.6 tons Pulpwood, 28.2 tons Sawtimber

Gain over 15 years = -1.3 tons Pulpwood, 25.9 tons Sawtimber

Gain over 15 years all products combined = 24.6 tons

Entities Without Reliable Inventory

- We could also use an appropriate growth and yield system and convert yield output to carbon tons as shown earlier
- Why would using a growth and yield model be preferred?
  - Can tailor the management more specifically to the stand(s) in question – this can be important if management intensity is more intensive than assumed for table development or if transaction requires more confidence in estimates

Questions/Comments?