

## **Growth, Yield and Carbon Balance Model**

### **For Planted Loblolly Pine**

#### **Model Version 1.32**

This model allows the user to simulate stand dynamics of planted loblolly pine forests under different management scenarios. The model allows simulating the following:

- Growth and Yield (Survival; Dominant Height; Basal Area; Total Merchantable Volume outside and inside bark; Merchantable Volume inside bark partitioning in 3 wood products: sawtimber, chip-and-saw and pulpwood).
- *In Situ* Biomass stock (aboveground, coarse roots, forest floor, coarse woody debris, standing dead and understory biomass).
- *Ex Situ* C stock (dynamics of C sequestered in forest products: sawtimber, chip-and-saw and pulpwood)
- Stand C balance (*In Situ* + *Ex Situ* – Emissions due to Silviculture)

## DISCLAIMER

By downloading and using the “Growth, Yield and Carbon Balance Model for Planted Loblolly Pine” you accept the following:

The “Growth, Yield and Carbon Balance Model for Planted Loblolly Pine” is provided "as is," without warranty of any kind, express or implied, including but not limited to the warranties of merchantability, fitness for a particular purpose and non-infringement. In no event shall the author be liable for any claim, damages or other liability, whether in an action of contract, tort or otherwise, arising from, out of or in connection with the software or the use or other dealings with the model system.

For any publication produced from the use of this model, please use the following citation:

C.A. Gonzalez-Benecke, T.A. Martin and E.J. Jokela. 2011. A flexible hybrid model of life cycle carbon balance of loblolly pine (*Pinus taeda* L.) management systems, *Forests* 2:749-776.

Thanks,

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## 1. TAB: INPUTS

In this tab the user should enter the initial characteristics and the management activities of the stand to simulate, and the units (English or Metric) of the outputs calculated by the model. The model needs initial stand characteristics to start simulation. The Growth and Yield model is based on the functions reported by Harrison and Borders (1996); the Carbon Balance Model is based on the functions reported by Gonzalez-Benecke et al. (2011)

- **Type of Simulation (A2:B4)**

Select simulation options by clicking the option button. The model can run from Establishment (**B3**) or from an inventory at any age post establishment (**B4**).

- If the type of simulation selected was “**From Establishment**”:
- **Enter stand data at planting: (A8:B10)**

Enter planting density (**B9**), unit: trees / acre

Enter site index (base age=50 years), (**B10**) unit: feet.

- If the type of simulation selected was “**From Inventory Post Establishment**” there are two options:

- a) **Simulation from Inventory Tree List: Click the option button in cell F9**

The user has to input **Inventory data list in TAB: INVENTORY**

**Important:** Do not input any data in tab “Inputs” cells **F14:F17**.

Go to tab “INVENTORY” by clicking button “Go To Inventory”.

Type or copy and paste a list (as column) of the diameter at breast height (DBH) of all trees in a single inventory plot (Column B, starting in cell **B4**), unit: inch.

If total HEIGHT of some or all inventory trees is available, also type or copy and paste in column C (starting in cell **C4**), unit: feet.

Enter stand age (**Q3**) at time of inventory, unit: years.

Enter inventory plot size (**Q4**), unit: acre.

If HEIGHT was measured in a subsample, the system calculates the missing heights in one of two ways:

- If HEIGHT was measured in more than 3 trees: missing HIEGHT is calculated using a local H-D function determined with the trees with HEIGHT and DBH measurements.
- If HEIGHT was measured in less than 4 trees: missing HIEGHT is calculated using a general H-D function published by Gonzalez-Benecke et al. (2015).

Note: For missing HEIGHT just leave blank cells. The system calculates stand density (**V4**), Basal Area (**V5**), Dominant Height (**V6**) and Site Index at base age=25 years (**V7**).

After checking that stand-level parameters in cells **V4:V7** were calculated, go back to INPUTS tab by clicking the button “Go To Inputs” in cell **Y4**.

**b) Simulation from Inventory Summary: Click the option button in cell F10**

If you already have summary data calculated from one or more measurement plots, you may enter Inventory Summary data (**G14:G17**)

- Enter stand age at time of inventory (**G14**), unit: years.
- Enter stand density (**G15**), unit: trees / acre.
- Input site index (base age=50 years) (**G17**), unit: feet.
- Optional: Input Basal Area (**G16**), unit ft<sup>2</sup> /acre.

Note: If BA is not available, the system calculates BA using stand Age, N/acre and SI (using the function reported in: Harrison and Borders, 1996).

- **Rotation Age (A6:B6)**

Enter in cell **B6** the rotations age (unit: years).

- **Select Physiographic Region (For Growth and Yield Modeling) (D1:D3)**

The model reported by Harrison and Borders (1996) have different for two macro regions in SE United States: i) Lower Coastal Plain and ii) Piedmont and Upper Coastal Plain (these two regions were pooled in one set of equations).

Select Physiographic zone by clicking the option button. If the user wants to simulate a stand located in Lower Coastal Plain, then select “**Lower Coastal Plain**” (**D2**). If the user wants to simulate a stand located in Piedmont or Upper Coastal Plain, then select “**Piedmont and Upper Coastal Plain**” (**D3**).

- **Units (Outputs) (F1:F3)**

Select units for **OUTPUT** by clicking the option button. If the user wants English units, then select “English” (**F2**). If the user wants Metric units, then select “Metric” (**F3**).

Note: all **INPUT** values should be entered in English units.

**SITE INDEX CALCULATOR:**

If the user wants to estimate SI at base age=25 yrs. using known dominant height and age, click the button “**Site Index Calculator**” in cell **P15**. The model use the function reported in: Harrison and Borders (1996).

- Enter dominant height (**B3**), unit: ft.
- Enter stand age (**B4**), unit: years.

**SIMULATING THINNINGS:**

If the user wants to simulate thinning, click the selection button “**Simulate Thinning?**” in cell **B12**.

The model can run up to 2 thinnings. The thinning method assumed is row-select combination at fixed age. The percentage removal is expressed in terms of trees/acre and the BA removal is determined using the equations reported in Harrison and Borders (1996).

If the user want to simulate thinning, has to enter thinning age (years) and percentage of N/acre removal (%) in cells **B15** to **C16**. If only 1 thinning will be simulated, the corresponding input cells should be left in blank (no zeros or any number).

**SILVICULTURAL TREATMENTS:**

The model can include the effects of different treatments of site preparation, weed control and fertilization.

- Herbaceous weed control (**A25** to **C38**): Select one of the options by clicking the option button in cells **C20:C31**. If No herbaceous weed control is the treatment, click the selection button in **C38**.
- Fertilization (**E30** to **H35**): The model can include up to 4 fertilizations. If the user want to simulate fertilization, has to enter fertilization age (years), and the amount of N and P applied each fertilization (lbs/acre) in cells **F32** to **H35**.

Even if fertilization age and doses (lbs/acre of N and P) were enter in cells **F32** to **H35**, the fertilizations should be activated by clicking the selection buttons in cells **E32** to **E35**.

- **Tillage (E21 to F22):** If Tillage is in the site preparation activities, clicking the selection button in cell **F21**.
- **Hardwood Release (E24 to F28):** If the user wants to simulate mid-rotation hardwood release effect on loblolly pine growth, click the selection button “**Hardwood Release?**” in cell **F24**. Also include the Age (yrs.) at which the hardwood release will be carried out (cell **F25**) the Percentage Reduction of Hardwoods (cell **F26**) and the percentage of hardwood basal area at age 5 (cell **F27**).

### **SIMULATING STAND GROWTH AND YIELD:**

If the user wants to simulate stand growth and yield, then click the button in cell **H2** (“**RUN Growth & Yield**”). The user will be directed to the TAB: “Report\_G&Yield” (if English units were selected in option button **F2**) or to the TAB: “Report\_G&Yield\_Metric” (if Metric units were selected in option button **F3**).

For further details on Growth and Yield Reports, please refer to TAB: “Report\_G&Yield”.

### **SIMULATING NET C BALANCE:**

If Carbon balance is to be simulated, the user should click the selection button in cell **B19** and select the number of rotations that should be included in Net C Balance estimations (**B20**). The maximum simulation length is 500 years, so the number of rotations entered multiplied by the rotation age should not be larger than 500 yrs.

After previous step, the user can click the button in cell **J2** (“**RUN C Balance**”). The user will be directed to the TAB: “**SUMMARY\_C**”, where a summary of *In Situ*, *Ex Situ* and Silviculture Emissions are shown as an average of yearly values for the simulation period. See TAB 6: **SUMMARY\_C** for further details.

Simulation options for Biomass and Carbon Dynamics:

- **Burning Residues at Site Prep.?:** The model can simulate the effects of prescribed burning on biomass harvest residues. If site preparation includes burning residues, then click the selection button in cell **B21**.
- **Stand Location:** Decay rate of coarse woody debris is estimated using the model reported by Radtke et al. (2006). Include coordinates (in decimal degrees) for latitude N (cell **F38**) and longitude –W (cell **F39**). Note that longitude W does not needs negative sign.

## 2. TAB: “REPORT\_G&Y” or “REPORT\_G&Y\_METRIC”

The tab shows a report of stand parameters at starting age and at rotation age after clicking the button “**RUN Growth & Yield**”. If thinning was carried out, details of stand characteristics after and before each thinning are shown.

If in “INPUT” TAB, the output unit selected was “English” (**F2**), the model will show the TAB: **REPORT\_G&Y**. If the output unit selected was “Metric” (**F3**), the model will show the TAB: **REPORT\_G&Y\_METRIC**.

The user can decide if yield output is presented as merchantable volume (inside or outside bark) or as green tons, inside or outside bark) by clicking one option button in cell **B32** (volume outside bark), **B33** (volume inside bark), **C32** (green tons outside bark) or **C33** (green tons inside bark). A volume to weight factor of 37.75 was used to transform ft<sup>3</sup> to green ton.

The units will be English if TAB: **REPORT\_G&Y** was displayed, or Metric if TAB: **REPORT\_G&Y\_METRIC** was displayed.

From this TAB the user also can:

- Run Carbon Balance Modeling, by clicking button “**RUN C Balance**” in cell **F31**.
- Start a new simulation, by clicking button “**New Simulation?**” in cell **G31**.
- Print a Report, by clicking button “**PRINT**” in cell **I31**.

### 3. TAB: “SUMMARY\_G&Y” or “SUMMARY\_G&Y\_METRIC”

The tab is shown as complimentary information when the TAB: **REPORT\_G&Y** was shown after clicking the button “**RUN Growth & Yield**”.

The tab shows a summary of stand parameters from the growth and yield model (from simulation starting age to rotation age).

If in “INPUT” TAB, the output unit selected was “English” (**F2**), the model will show the TAB: **SUMMARY\_G&Y**. If the output unit selected was “Metric” (**F3**), the model will show the TAB: **SUMMARY\_G&Y\_METRIC**.

At each age, details of N (stand density), Hdom (dominant height), BA (basal area), Dq (quadratic mean diameter), SDI (stand density index), VOB (Merchantable stem volume outside bark), VIB (Merchantable stem volume inside bark), VIB-ST (sawtimber volume inside bark), VIB-CNS (chip-and-saw volume inside bark) and VIB-PW (pulpwood volume inside bark). Also Current Annual Increment in basal area (CAI-BA) and stem volume outside Bark (CAI-VOB), and Mean Annual Increment in basal area (MAI-BA) and stem volume outside bark (MAI-VOB) are displayed.

The units will be English if TAB: **SUMMARY\_G&Y** was displayed, or Metric if TAB: **SUMMARY\_G&Y\_METRIC** was displayed.

The user should go to TAB: **REPORT\_G&Y** for further actions as Run Carbon Balance or Run a New Simulation.

#### 4. TAB: “SUMMARY\_C” or “SUMMARY\_C\_METRIC”

The tab shows a report of Carbon Stock Modeling after clicking the button “**RUN C Balance**”.

If in “INPUT” TAB, the output unit selected was “English” (**F2**), the model will show the TAB: **SUMMARY\_C**. If the output unit selected was “Metric” (**F3**), the model will show the TAB: **SUMMARY\_C\_METRIC**.

In this tab a summary of *In Situ*, *Ex Situ* and Silviculture Emissions are shown as an average of yearly values for the simulation period.

This tab also shows the dynamics of the *In Situ* (Living loblolly pine, Forest floor, Dead Pool – standing dead, harvest residues and CWD – and Understory) and *Ex Situ* (forest products sawtimber, chip-and-saw and pulpwood) Carbon Pools. Three figures are displayed in this report: A bar graph showing the average values of *In Situ* C stock (Living Loblolly Pine, Forest Floor, Dead Loblolly Pine and Understory), *Ex Situ* C stock (sawtimber, chip-and-saw, and pulpwood) and Silviculture Emissions. Also two line graphs show the time series of *In Situ* and *Ex Situ* C Stock, from simulation starting age to rotation age at last rotation selected.

The units will be English (ton C /acre) if TAB: **SUMMARY\_C** was displayed, or Metric (tonne C / ha) if TAB: **SUMMARY\_C\_METRIC** was displayed.

Note: The model does not include soil C dynamics. The model assumes that soil C is in steady state condition.

From this TAB the user also can:

- Run Growth and Yield Modeling, by clicking button “**RUN Growth and Yield**” in cell **V2**.
- Start a new simulation, by clicking button “**New Simulation?**” in cell **V7**.
- Print a Report, by clicking button “**PRINT**” in cell **V11**.

#### 5. TAB: “IN\_SITU” or “IN\_SITU\_METRIC”

The tab is shown as complimentary information when the TAB: **SUMMARY\_C** was shown after clicking the button “**RUN C Balance**”.

This tab shows the *In Situ* biomass of the stand. Details of Living Loblolly Pine (stemwood, bark, foliage, branch and coarse roots), Dead Loblolly Pine (standing dead, forest floor, thinning and harvest residues) and Understory Biomass at each simulation age are shown. Also Longleaf Pine projected leaf area index (LAI, m<sup>2</sup> / m<sup>2</sup>) is presented.

Above-ground biomass functions from Baldwin (1987). Coarse root and tap root biomass functions from Samuelson et al. (2004). LAI, Understorey Biomass, Needlefall and Litterfall functions from Gonzalez-Benecke et al. (2010 and 2011).

If in “INPUT” TAB, the output unit selected was “English” (F2), the model will show the TAB: **IN\_SITU**. If the output unit selected was “Metric” (F3), the model will show the TAB: **IN\_SITU\_METRIC**.

The units will be English if TAB: **IN\_SITU** was displayed, or Metric if TAB: **IN\_SITU\_METRIC** was displayed.

The user should go to TAB: **SUMMARY\_C** for further actions as Run Growth and Yield or Run a New Simulation.

## 6. TAB: “EX\_SITU” or “EX\_SITU\_METRIC”

The tab is shown as complimentary information when the TAB: **SUMMARY\_C** was shown after clicking the button “**RUN C Balance**”.

This tab shows the dynamics of the *Ex Situ* Carbon Pool. Details of C sequestered in forest products sawtimber (ST), chip-and-saw (CNS) and pulpwood (PW) is presented, assuming industrial conversion efficiencies and product proportion in 4 half-life classes defined in TAB: EQUATION – PARAMETERS, CELLS **A263** to **F267**.

If in “INPUT” TAB, the output unit selected was “English” (F2), the model will show the TAB: **EX\_SITU**. If the output unit selected was “Metric” (F3), the model will show the TAB: **EX\_SITU\_METRIC**.

The units will be English if TAB: **EX\_SITU** was displayed, or Metric if TAB: **EX\_SITU\_METRIC** was displayed.

The user should go to TAB: **SUMMARY\_C** for further actions as Run Growth and Yield or Run a New Simulation.

## 7. TAB: “C\_STOCK” or “C\_STOCK\_METRIC”

The tab is shown as complimentary information when the TAB: **SUMMARY\_C** was shown after clicking the button “**RUN C Balance**”.

This tab shows the dynamics of the *In Situ* (Living longleaf pine, Forest floor, Dead Pool – standing dead, harvest residues and CWD – and Understory), *Ex Situ* (forest products sawtimber, chip-and-saw and pulpwood) and Emissions due to Silviculture Carbon Pools.

If in “INPUT” TAB, the output unit selected was “English” (F2), the model will show the TAB: **C\_STOCK**. If the output unit selected was “Metric” (F3), the model will show the TAB: **C\_STOCK\_METRIC**.

The units will be English if TAB: **C\_STOCK** was displayed, or Metric if TAB: **C\_STOCK\_METRIC** was displayed.

The user should go to TAB: **SUMMARY\_C** for further actions as Run Growth and Yield or Run a New Simulation.

There are other hidden tabs:

## 8. TAB: EQUATIONS - PARAMETERS

This tab is hidden and protected and the user should not change it.

If the user wants to view the equations and parameters used in this model system, then click the button “**Edit Equations / Parameters**” in TAB: INPUTS, cell **P2**.

If the user wants to make changes to some of the parameters the spread sheet can be unprotected by using a password that may be provided on request from the model administrator at [www.carboncenter.ifas.ufl.edu/models/](http://www.carboncenter.ifas.ufl.edu/models/)

This TAB shows details of function parameters for growth and yield (cells **A1** to **K144**; Harrison and Borders 1996); loblolly pine biomass (cells **A150** to **U196**; Baldwin 1987; Samuelson et al; 2004); LAI, Needlefall, needlefall/litterfall ratio (cells **A199** to **K215**; Gonzalez-Benecke et al. 2011), Wood Specific Gravity as a function of age (cell **A219** to **K223**); Peter et al. 2007); Coarse Woody Debris Decay Rate (cells **A225** to **K229**; Radtke et al. 2009); Understory Biomass (cells **A231** to **J233**; Gonzalez-Benecke et al. 2010).

Other parameters showed: Carbon Concentration in biomass, decay rate, specific needle area, product (sawtimber, chip-and-saw, pulpwood) diameter threshold and half-life , percentage of commercial volume in residues after harvest, percentage of consumption by fire (for needles, branches, coarse woody debris, standing dead trees and understory; Reinhardt 2003).

Silviculture cost for different management activities such as site preparation, machine planting, weed control, fertilization, prescribed burning, thinning, harvest and transport are shown in cells **A273** to **B286** (Markewitz 2005; Chapagain 2012).

To go back to TAB: INPUTS, click the button “Go To Inputs” in cell **L2**.

## 9. TAB: GROWTH\_&\_YIELD

This tab shows details of all computations for the growth and yield model.

This tab is hidden and protected and the user should not change it.

## REFERENCES.

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