

Growth, Yield and Carbon Balance Model

For Planted Slash Pine

Model Version 1.32

This model allows the user to simulate stand dynamics of planted slash 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 Slash Pine” you accept the following:

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

C.A. Gonzalez-Benecke, T.A. Martin, W.P. Cropper Jr. and R. Bracho. 2010. Forest management effects on *in situ* and *ex situ* slash pine forest carbon balance. *Forest Ecology and Management* 260:795-805.

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 Pienaar et al. (1996), Martin et al. (1997) and Yin et al. (1998); the Carbon Balance Model is based on the functions reported by Gonzalez-Benecke et al. (2010)

- **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 Inventory Post Establishment**” there are two options:

a) **Simulation from Inventory Tree List: THIS OPTION IS NOT IMPLEMENTED IN THE CURRENT VERSION OF THE MODEL.**

b) **Simulation from Inventory Summary: Click the option button in cell E10**

If you already have summary data calculated from one or more measurement plots, you may enter Inventory Summary data (**F14:F17**)

- Enter stand age at time of inventory (**F14**), unit: years.
- Enter stand density (**F15**), unit: trees / acre.
- Input site index (base age=50 years) (**F17**), unit: feet.
- Optional: Input Basal Area (**F16**), unit ft² /acre.

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

- **Select Soil Type (For Growth and Yield Modeling) (D1:D4)**

The model reported by Martin et al. (1997) have different responses to fertilization for three main soil types in SE United States using the Cooperative Research In Forest Fertilization (CRIFF) classification: i) Soil Type B:

Arenic Paleaquult, ii) Soil Type C: Ultic Haplaquod and iii) Soil Type D: Grossarenic Haquaplod (further details on CRIF soil classification can be found at Kushla and Fisher (1980).

Select Soil Type by clicking the option button. If the user wants to simulate a stand located in Soil Type D, then select “**D**” (**D2**). If the user wants to simulate a stand located in Soil Type C, then select “**C**” (**D3**). If the user wants to simulate a stand located in Soil Type B, then select “**B**” (**D4**).

- **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.

- **Enter stand data at planting: (A9:B10)**

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

Enter site index (base age=25 years), (**B10**) unit: feet.

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

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

SILVICULTURAL TREATMENTS:

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

- **Bedding (A13 to B13)**. If Bedding is in the site preparation activities, the user should click the selection button in cell **B13**.
- **Weed control (A14 to B14)**: If weed control is in the establishment activities, the user should click the selection button in cell **B14**.
- **Fertilization (A17 to B23)**: The user should select if the fertilization includes only Nitrogen (click the option button in cell **B17**) or Nitrogen and Phosphorus (click the option button in cell **B18**). The model can include up to 4 fertilizations. If the user want to simulate fertilization, has to enter fertilization age (years) in cells **B20 to B23**. If less than 4 fertilization want to be simulated; only the corresponding cells should be entered.

Even if fertilization with N or N+P was selected in cells **B17** or **B18**, the fertilizations should be activated only if any fertilization age was entered in cells **B20** to **B23**.

SIMULATING THINNINGS:

If the user wants to simulate thinning, click the selection button “**Simulate Thinning?**” in cell **B26**.

The model can run up to 4 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 Pienaar et al. (1995).

If the user want to simulate thinning, has to enter thinning age (years) and percentage of N/acre removal (%) in cells **B30** to **C32**. If less than 4 thinnings want to be simulated; only the corresponding cells should be entered. For example if only 1 thinning will be simulated, the corresponding input cells for thinning 2, 3 and 4 should be left in blank (no zeros or any number).

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 **E21** and select the number of rotations that should be included in Net C Balance estimations (**E22**). 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 **H5** (“**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 **E23**.

- **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 **E26**) and longitude –W (cell **E27**). Note that longitude W does not need negative sign.

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 ft³ 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 **H31**.
- Print a Report, by clicking button “**PRINT**” in cell **I31**.

2. 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.

3. 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 **X3**.
- Start a new simulation, by clicking button “**New Simulation?**” in cell **X7**.
- Print a Report, by clicking button “**PRINT**” in cell **X11**.

4. 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, coarse and fine 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, m² / m²) is presented.

Above-ground, coarse root, fine root and understory biomass functions from Gonzalez-Benecke et al (2010). LAI, Needlefall and Litterfall biomass functions from Gonzalez-Benecke et al. (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.

5. 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 **A254** to **F262**.

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.

6. 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:

7. 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 **N2**.

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/

This TAB shows details of function parameters for growth and yield (cells **A1** to **K60**; Pienaar et al. 1996; Martin et al. 1997; Yin et al. 1998); loblolly pine biomass (cells **A62** to **K86**; Gonzalez-Benecke et al. 2010); LAI, Needlefall, needlefall/litterfall ratio (cells **A92** to **K106**; Gonzalez-Benecke et al. 2011), Understory Biomass (cells **A107** to **K109**; Gonzalez-Benecke et al. 2010); Wood Specific Gravity as a function of age (cell **A110** to **K114**); Gonzalez-Benecke et al. 2010); Coarse Woody Debris Decay Rate (cells **A115** to **K119**; Radtke et al. 2009).

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 **A153** to **B166** (Markewitz 2005; Chapagain 2012).

To go back to TAB: INPUTS, click the button “Go To Inputs” in cell **N2**.

8. 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.

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