



Growth, Yield and Biomass Dynamics Model For Even-Aged Natural Longleaf Pine Stands

This model allows the user to simulate stand dynamics of even-aged naturally regenerated longleaf 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).
- Pinestraw production (pinestraw production from current year needlefall).
- *In Situ* Biomass stock (aboveground, coarse roots, forest floor, coarse woody debris, standing dead and understory).
- Effects of prescribed burning on forest floor, coarse woody debris and understory biomass.



DISCLAIMER

By downloading and using the “Growth, Yield and Biomass Dynamics Model for Even-Aged Naturally Regenerated Longleaf Pine” you accept the following:

The “Growth, Yield and Biomass Dynamics Model for Even-Aged Naturally Regenerated Longleaf 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.

Thanks,

Carlos A. Gonzalez Benecke



ACKNOWLEDGEMENT

This research was supported by the U.S. Department of Defense, through the Strategic Environmental Research and Development Program (SERDP). The authors acknowledge the U.S. Forest Service Southern Research Station for their assistance and for providing the long term datasets.

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 Lauer and Kush (2011).

- **Units (Outputs) (D2:D4)**

Select units for **OUTPUT** by clicking the option button. If the user wants English units, then select “English” (**D3**). If the user wants Metric units, then select “Metric” (**D3**).

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

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

Select simulation options by clicking one option button. The model can run **From Inventory Tree List (B3)** or **From an Inventory Summary (B4)**.

- **Simulation Length (A6:B6)**

Enter in cell **B6** the age when simulation ends (unit: years). We suggest not using the model beyond age 120 years.

Simulation options:

Already Thinned?: If the stand was thinned before inventory, the user has to click the selection button in cell **B8**.

Age to reach DBH: Enter the average age (years) when the stand reached DBH height (**B9**). The default value is 7 years (Lauer and Kush, 2011).

a) Simulation from Inventory Tree List: Click the option button in cell B3

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

Important: Do not input any data in tab “Inputs” cells **B15:B18**.

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 at cell **B4**), unit: inch

If HEIGHT is available, also type or copy and paste in column C (starting at cell C4) unit: feet

Enter stand age (Q3) unit: years

Enter 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. (2013).

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=50 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 selection button in cell B4

If you already have summary data calculated from one or more measurement plots, you may enter Inventory Summary data (**C15:C18**)

- Enter stand age at time of inventory (**C15**), unit: years.
- Input stand density (**C16**), unit: trees / acre.
- Input site index (base age=50 years) (**C18**), unit: feet.
- Optional: Input Basal Area (**C17**), 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: Lauer and Kush 2011).

SITE INDEX CALCULATOR:

If the user wants to estimate SI at base age=50 yrs. using known dominant height and age, click the button “**Site Index Calculator?**” in cell **F16**. The model use the function reported in: Gonzalez-Benecke et al. 2012b).

- 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 **B11**.

The model can run up to 4 thinnings. The thinning method is from below.

Select thinning type by clicking one option button in cells **B22:B23**. The model can simulate thinning at fixed Age (**B22**), or at Target BA (**B23**).

After selecting the thinning type, the user should select the removal criteria by clicking one option button in cells **B26:B27**. The user should enter if the removal criteria is Basal Area (**B26**) or Living Trees (**B27**).

- **Thinning at fixing age:** The user can simulate up to 4 thinnings. The user has to enter thinning age (years) and percentage of removal (%) in cells **B30** to **C33**. If less than 4 thinnings will be simulated, the corresponding input cells should be left in blank (no zeros or any number).
- **Thinning at Target BA:** The user enters the Target BA (Upper Stocking Limit BA, cell **A36**) at which thinning is triggered and the residual BA (**B36**) after the thinning. Unit: ft² / acre. Depending on stand characteristics (age, N/acre and SI), the model can simulate up to 4 thinnings.

SIMULATING STAND GROWTH AND YIELD:

If the user wants to simulate stand growth and yield, then click the button in cell **E2** (“**RUN Growth & Yield**”). The user will be directed to the TAB: “Report_G&Yield” (if English units were selected in option button **D3**) or to the TAB: “Report_G&Yield_Metric” (if Metric units were selected in option button **D4**).

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

SIMULATING C DYNAMICS:

If C dynamics modeling wants to be presented, the user has to click the button in cell D2 (“**Run C Dynamics**”). The user will be directed to the TAB: “Summary C”, where a summary of In Situ C stock is shown as an average of yearly values for the simulation period. Three figures are displayed in this report: A bar graph showing the average values of *In Situ* C stock (Living Longleaf Pine Above-Ground, Living Longleaf Pine Below-Ground, Forest Floor, Dead Longleaf Pine and Understory). Also two line graphs show the time series of Living and Dead C Stock.

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

See TAB 6: **SUMMARY_C** for further details.

SIMULATE PRESCRIBED BURNING:

The model can simulate the effects of prescribe burning on biomass dynamics of understory, forest floor, coarse woody debris and standing dead trees.

- If prescribed burning is to be included in stand biomass dynamics simulation, the stand Age at first burning (in years) should be enter in cell **E9** and the burning frequency (in years) should be entered in cell **E10**.
- If the stand was previously burned, the user should click the selection button in cell **E11**.
- In order to simulate understory biomass recovery after burning, the user should select one of the 3 types of sites by clicking the option button in cell **F9** (xeric site), **F10** (intermediate site) or **F11** (mesic site).
- The biomass dynamics of two types of understory can be simulated: **Herbaceous** (using the model reported by Grelen and Lohrey 1978) or **Shrubs** (using the model reported by Gonzalez-Benecke et al. 2010). The user has to select the type of understory by clicking the option button in cell **G9** (herbaceous) or **G10** (shrubs).

Note: If prescribed burning will not be included as a management alternative, please leave blank cells **E9** and **E10**. At this time the model assumes no effect of prescribed burning on longleaf pine stand mortality. A function to determine the proportion of dead trees after burning will be incorporated in a future version.

At this time, the model only includes one function for shrubs, independent of site type. Separated functions for xeric, intermediate and mesic sites will be incorporated in a future version.

2. TAB: INVENTORY

This TAB is revealed when the Button “Go To Inventory” is clicked in Cell **M11** (needed to determine initial parameters when simulation From Inventory Post Establishment (**B4**) using Inventory Tree List (**E7**) option buttons were selected as simulation method).

- Type or copy and paste a list (as column) of all DBH in the inventory plot (Column B, starting in cell **B4**), unit: inch
- If HEIGHT is available, also type or copy and paste in column C (starting in cell **C4**), unit: feet
- Enter stand age at time of inventory (**Q3**), 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 HEIGHT 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 HEIGHT is calculated using a general H-D function published by Gonzalez-Benecke et al. (2013).

Note: The system calculate stand density (**V4**), Basal Area (**V5**), Dominant Height (**V6**) and Site Index at base age=50 years (**V7**).

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

3. 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” (D3), the model will show the TAB: **REPORT_G&Y**. If the output unit selected was “Metric” (D4), 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).

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 **E31**.
- Start a new simulation, by clicking button “**New Simulation?**” in cell **G31**.
- Print a Report, by clicking button “**PRINT**” in cell **H31**.

4. 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” (D3), the model will show the TAB: **SUMMARY_G&Y**. If the output unit selected was “Metric” (D4), the model will show the TAB: **SUMMARY_G&Y_METRIC**.

At each age, details of N (stand density), Hdom (dominat 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-VOB) 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.

5. TAB: “PINESTRAW” or “PINESTRAW_METRIC”

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

If in “INPUT” TAB, the output unit selected was “English” (**D3**), the model will show the TAB: **Pinestraw**. If the output unit selected was “Metric” (**D4**), the model will show the TAB: **Pinestraw_METRIC**.

This tab shows the pinestraw production (from simulation starting age to rotation age). If bale weight is entered in cell **G2** and pinestraw harvest efficiency (%) is entered in cell **H2**, the model will estimate bale production each year. The system assumes no effect of prescribed burning.

The units will be English if TAB: **Pinestraw** was displayed, or Metric if TAB: **Pinestraw_METRIC** was displayed.

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

6. TAB: “SUMMARY_C” or “SUMMARY_C_METRIC”

The tab shows a report of *In Situ* Carbon Dynamics after clicking the button “**RUN C Balance**”.

If in “INPUT” TAB, the output unit selected was “English” (D3), the model will show the TAB: **SUMMARY_C**. If the output unit selected was “Metric” (D4), the model will show the TAB: **SUMMARY_C_METRIC**.

In this tab a summary of *In Situ* C stock is shown as an average of yearly values for the simulation period.

This tab also shows the dynamics of the *In Situ* (Living longleaf pine, Forest floor, Dead Pool – standing dead, harvest residues and CWD – and Understory) Carbon Pool. Three figures are displayed in this report: A bar graph showing the average values of *In Situ* C stock (Living Longleaf Pine Above-Ground, Living Longleaf Pine Below-Ground, Forest Floor, Dead Longleaf Pine and Understory). Also two line graphs show the time series of Living Vegetation and Dead Vegetation Pools 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 **X2**.
- Start a new simulation, by clicking button “**New Simulation?**” in cell **X6**.
- Print a Report, by clicking button “**PRINT**” in cell **X10**.

7. TAB: “BIOMASS or BIOMASS_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 Longleaf Pine (stemwood, bark, foliage, branch and coarse roots), Dead Longleaf 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 biomass functions from Baldwin and Saucier (1983). Coarse root biomass function from Santantonio et al (1977). Needlefall assumes two years needle retention.

If in “INPUT” TAB, the output unit selected was “English” (D3), the model will show the TAB: **BIOMASS**. If the output unit selected was “Metric” (D4), the model will show the TAB: **BIOMASS_METRIC**.

The units will be English if TAB: **BIOMASS** was displayed, or Metric if TAB: **BIOMASS_METRIC** was displayed.

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

8. 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) Carbon Pool.

If in “INPUT” TAB, the output unit selected was “English” (D3), the model will show the TAB: **C_STOCK**. If the output unit selected was “Metric” (D4), 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:

9. 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 **Q2**.

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 **A4** to **N70**; Lauer and Kush 2010, 2011), longleaf pine biomass (cells **A82** to **N104**; Baldwin and Saucier 1983), needlefall/litterfall ratio (cells **A105** to **N108**; Gonzalez-Benecke et al., 2012), understory biomass (cells **A102** to **J104**; Gonzalez-Benecke et al., 2010), forest floor accumulation (cells **A112** to **N116**) and standing dead longleaf pine biomass (cells **A117** to **N119**).

Other parameters are also shown: Carbon Concentration in biomass (**F121**), decay rates for needles (**F123**), coarse woody debris (**F124**) and root (**F125**), specific needle area (**F126**), percentage of consumption by fire (for needles, branches, coarse woody debris, standing dead trees and understory; **F132:F136**; Reinhardt 2003), and function parameters for fuel consumption recovery for understory are shown in rows **140** to **142** (models fitted from: Digital Photo Series <http://depts.washington.edu/nwfire/dps/>; Kirkman et al 2001; Lavoie et al 2010).

To go back to TAB: INPUTS, click the button “Go To Inputs” in cell **P2**.

10. 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.

- Baldwin Jr., V.C., and J.R. Saucier. 1983. Aboveground weight and volume of unthinned, planted longleaf pine on West Gulf forest sites. Res. Paper SO-191. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, 25 pp.
- Gonzalez-Benecke, C.A., 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.
- Gonzalez-Benecke, C.A., E.J. Jokela and T.A. Martin. 2012. Modeling the effects of stand development, site quality, and silviculture on leaf area index, litterfall, and forest floor accumulation in loblolly and slash pine plantations, *Forests Science* 58: 457-471.
- Gonzalez-Benecke, C.A., S.A. Gezan, T.A. Martin, W.P. Cropper Jr., and L.J. Samuelson and D.J. Leduc. 2013. Individual tree diameter, height and volume functions for longleaf pine (*Pinus palustris* Mill.), *Forests Science*. In Press.
- Grenlen, H.E., and R.E. Lohrey. 1978. Herbage yield related to basal area and rainfall in a thinned longleaf plantation. Res. Note SO-232, 4 pp.
- Kirkman, L.K., Mitchell R.J., Helton R.C., and Drew M.B. 2001. Productivity and species richness across an Environmental gradient in a fire-dependent ecosystem. *American Journal of Botany*, 88:2119-2128.
- Lavoie, M., Starr G., Mack, M.C., Martin T.A., and Gholz H.L. 2010. Effects of a prescribed fire on understory vegetation, carbon pools and soil nutrients in a longleaf pine – slash pine forest in Florida. *Natural Areas Journal* 30: 82-94.
- Lauer, D.K. and Kush, J.S. 2010. Dynamic Site Index Equation for Thinned Stands of Even-Aged Natural Longleaf Pine. *Southern Journal of Applied Forestry*, 34:28-37.
- Lauer, D.K. and Kush, J.S. 2011. A variable density stand level growth and yield model for even-aged natural longleaf pine. Special Report No 10 Alabama Agricultural Experiment Station, Auburn University, Auburn, Alabama, 15 pp.
- Reinhardt, E.D. 2003. Using FOFEM 5.0 to estimate tree mortality, fuel consumption, smoke production and soil heating from wildland fire. Page P5.2 in: Proceedings of the Second International Wildland Fire Ecology and Fire Management Congress and Fifth Symposium on Fire and Forest Meteorology. American Meteorological Society, 16-20 November 2003, Orlando, Florida, USA.
- Santantonio, D., Hermann, R.K., Overton, W.S. 1977. Root biomass studies in forest ecosystems. *Pedobiologia Band* 17:1-31.