



## Integrated Model for Growth, Yield and *In Situ* Biomass for

### Planted Southern Pines

#### Model Version 1.1

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

- Growth and Yield module returns a table with stand Initial Values, and a results table with stand parameters at Rotation Age including: Age, Stem Density (i.e., number of surviving trees per acre), Quadratic Mean Diameter (Dq), Dominant Height (Hdom), Basal Area (BA), as well as Total Merchantable Volume either outside or inside bark expressed in units of volume or weight partitioned into Sawtimber, Chip-and-Saw, and Pulpwood. In addition, four graphs are produced showing Trees per Acre, Dominant Height, Basal Area and Merchantable Volume Inside Bark changes over time either since planting or since inventory time until the rotation age.
- *In Situ* Biomass module returns a table with stand Initial Values, and a results table with biomass components at Rotation Age including: Age, Stem Density (i.e., number of surviving trees per acre), Stem Inside Bark (IB), Bark, Foliage, Branch, Coarse Root, Forest Floor – Needles, Forest Floor – Branches, Understory, Snags, and Thinning Residues (all biomass components in dry tons per acre). In addition, two graphs are produced showing Stem Inside Bark Biomass and Coarse Root Biomass over the time of simulation; as well as two bar charts showing Living *In Situ* Biomass at Rotation Age, and Dead *In Situ* Biomass at Rotation Age partitioned into different components for the species simulated.

Note: Biomass stock outputs are in units dry ton per acre. They can be transformed to Carbon by using a conversion factor of 0.5.



## DISCLAIMER

By downloading and using the “Integrated Growth, Yield and *In Situ* Biomass Model for Planted Southern Pines” you accept the following:

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

C.A. Gonzalez-Benecke, L.J. Samuelson, T.A. Martin, W.P. Cropper, Jr., T.A. Stokes, J. R. Butnor, K.H. Johnsen and P.H. Anderson. 2015. Modeling the effects of forest management on in situ and ex situ longleaf pine forest carbon stocks, *Forest Ecology and Management* 355: 24-36.

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.

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

The model needs initial stand characteristics to start simulation. In this tab the user should enter the initial characteristics and the management activities of the stands to simulate. The Growth and Yield models and the *In Situ* Biomass models are based on the functions reported by Gonzalez-Benecke et al. (2010, 2011 and 2015) adapted to work in English units.

- **Type of Simulation (A3: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**).

- **Select Species to Simulate (F2:G4)**

Select southern pine species to simulate by clicking the option button. The model can simulate growth and stand dynamics for loblolly (**G2**), slash (**G3**) and/or longleaf (**G4**) pine. The user can select one, two or the three species and run the model to compare species performance under given management and site quality characteristics.

- **Rotation Age (B7:D7)**

Enter the age when simulation ends for loblolly (**B7**), slash (**C7**) and/or longleaf (**D7**) (unit: years). We suggest not using the model beyond age 40 years for loblolly and slash, and 80 years for longleaf.

- **Site Index (B8:D8)**

Enter the site index (base age = 25 years for loblolly and slash pine; base age = 50 years for longleaf pine) for loblolly (**B8**), slash (**C8**) and/or longleaf (**D8**) (unit: feet).



- **Comparable Site Index Calculator (L1:R6)**

Comparable site index (base age = 25 years for loblolly and slash pine; base age = 50 years for longleaf pine) can be calculated if the value for a reference species is known. For example, if the dominant height (ft) and age (years) are known for loblolly pine, then the comparable site index for slash and longleaf pine can be determined by entering the known dominant height and age on cells **M4** and **N4**. The corresponding site index for loblolly (base age = 25 years), slash (base age = 25 years) and longleaf (base age = 50 years) will be displayed on cells **O4**, **Q4** and **R4**, respectively (unit: feet).

Important: Do not edit cells **O4 to R6**. Only enter values in grey cells **M4 to N6**.

- If the type of simulation selected was “**From Planting**”: Enter stand data at planting: (**B12 to D13**)

Enter planting density (trees per acre, TPA) for loblolly (**B12**), slash (**C12**) and/or longleaf (**D12**).

Enter first year survival loblolly (**B13**), slash (**C13**) and/or longleaf (**D13**) unit: % (default value =95%)

- If the type of simulation selected was “**From Inventory Post Establishment**” : Enter Inventory Summary data (**B17 to D19**)

Enter stand age at time of inventory for loblolly (**B17**), slash (**C17**) and/or longleaf (**D17**) (unit: years).

Enter stand density (trees per acre, TPA) at time of inventory for loblolly (**B18**), slash (**C18**) and/or longleaf (**D18**).

Optional: Enter basal area at time of inventory for loblolly (**B19**), slash (**C19**) and/or longleaf (**D19**) (unit: ft<sup>2</sup> /acre).

Note: If BA is not available, the system calculates BA using stand Age, TPA and SI (using the functions reported in: Gonzalez-Benecke et al. 2010, 2011 and 2015).

For loblolly pine, minimum stand density allowed is 101 TPA.



### **SIMULATING THINNINGS:**

If the user wants to simulate thinning, click the selection button “**Simulate Thinning?**” in cell **B21**.

The model can run up to 2 thinnings for loblolly and 4 thinnings for slash and longleaf. The thinning method is random (same proportion of BA and N is removed at each thinning and there is no change in quadratic mean diameter after and before thinning) and a fixed age

- The user has to enter thinning age (years) and percentage of removal (%) in cells **B24** to **G27**. For slash and longleaf, if less than 4 thinnings will be simulated, the corresponding input cells should be left in blank (no zeros or any number). As thinning is random, the same % of BA and trees/acre are removed each thinning.

### **TIMBER PRODUCTS CLASS DIAMETERS:**

The user can modify the product class diameters for sawtimber, chip-and-saw and pulpwood in cells **M13** to **N15**.

For sawtimber, enter minimum DBH over bark (**M13**) and top diameter, Dmin (**N13**) (unit: inch)

For chip-and-saw, enter minimum DBH over bark (**M14**) and top diameter, Dmin (**N14**) (unit: inch)

For pulpwood, enter minimum DBH over bark (**M15**) and top diameter, Dmin (**N15**) (unit: inch)

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

If the user wants to simulate stand growth and yield, then click the button in cell **F7** (“**RUN Growth & Yield**”). The user will be directed to the TAB: “**G&Y report**”, where a summary of stand parameters at starting age and at rotation age is shown. See TAB 2: **G&Y report** for further details.

### **SIMULATING *IN SITU* BIOMASS:**

If *In Situ* Biomass is to be simulated, the user should click the selection button in cell **F10** (“**RUN *IN SITU* BIOMASS**”). The user will be directed to the TAB: “**report\_biomass**”), where, for each species, a summary of the different components of the *in situ* biomass pools at the end of the simulation period is shown. See TAB 3: **report\_biomass** for further details.



## 2. TAB: "G&Y REPORT"

The tab shows, for each species simulated, a report of stand parameters at starting age and at rotation age after clicking the button "RUN Growth & Yield".

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 **B22** (volume outside bark), **B23** (volume inside bark), **C22** (green tons outside bark) or **C23** (green tons inside bark). A volume to weight factor of 37.75 was used to transform ft<sup>3</sup> to green ton.

As additional information, this tab also show 4 figures comparing the time series of loblolly (**red**), slash (**blue**) and longleaf (**green**) for TPA, basal area, dominant height and volume inside bark, from the age of simulation starting until the rotation age.

From this TAB the user also can:

- Start a new simulation, by clicking button "Go To Inputs" in cell **I5**.
- Print a Report, by clicking button "Print Report" in cell **I12**.
- Go to annual outputs report, by clicking button "Go To Annual Outputs" in cell **I17**.

### Growth and Yield annual outputs:

The tab called "summary" is shown as additional information after clicking the button "Go To Annual Outputs" in tab "G&Y\_report".

In this tab, a detail of yearly outputs from simulation starting age to rotation age is displayed for each species simulated. Stand parameters displayed in this report are: Age (years), TPA (living trees per acre), Hdom (dominant height, ft), BA (basal area, ft<sup>2</sup>/acre), Dq (quadratic mean diameter, inch), SDI (stand density index (trees per acre), VOB (volume outside bark, ft<sup>3</sup>/acre), VOB-ST (sawtimber volume outside bark, ft<sup>3</sup>/acre), VOB-CNS (chip-and-saw volume outside bark, ft<sup>3</sup>/acre), VOB-PW (pulpwood volume outside bark, ft<sup>3</sup>/acre), VIB (volume inside bark, ft<sup>3</sup>/acre), VIB-ST (sawtimber volume inside bark, ft<sup>3</sup>/acre), VIB-CNS (chip-and-saw volume inside bark, ft<sup>3</sup>/acre), VIB-PW (pulpwood volume inside bark, ft<sup>3</sup>/acre).

From the tab "summary" the user also can:

- Start a new simulation, by clicking button "Go To Inputs" in cell **A2**.
- Go to G&Y report, by clicking button "Go To G&Y Report" in cell **A9**.



### 3. TAB: “REPORT\_BIOMASS”

The tab shows a report of *in situ* biomass after clicking the button “**RUN *In Situ* Biomass**”.

The first part of the table shows, for each simulated species, a summary of stand initial parameters age, stem density (TPA), quadratic mean diameter (Dq), Dominant height (Hdom), basal area (BA) and site index (SI).

The second part of the table shows, for each simulated species, a summary of the *In Situ* biomass of the stand at rotation age (unit: dry ton/acre), including age, stem density (TPA) and details of Living Biomass (stemwood, bark, foliage, branch and coarse roots) and Dead Biomass (needles in forest floor, branches in forest floor, understory, snags and thinning residues) are shown in rows 13 to 22. Thinning residues included crown + coarse root of thinned trees.

As additional information, this tab also show 2 figures comparing the time series of loblolly (**red**), slash (**blue**) and longleaf (**green**) for stemwood (left) and coarse root (right) biomass, from the age of simulation starting until the rotation age.

Additional figures of biomass stock at the year of rotation end are also shown. Living Biomass (stemwood, bark, foliage, branch and coarse roots) is shown on the left panel and Dead Biomass (needles in forest floor, branches in forest floor, understory, snags and thinning residues) is shown in the right panel.

For loblolly and slash pine, above-ground biomass was computed using the functions reported by Gonzalez-Benecke et al (2014) and coarse root biomass was estimated from the root/stem ratio function reported by Gonzalez-Benecke et al. (2016). For longleaf pine, the above and below ground biomass was computed using the functions reported by Samuelson et al. (2014).

For loblolly and slash pine, needlefall was computed using the functions reported by Gonzalez-Benecke et al (2012). For longleaf pine, needlefall was estimated from foliage biomass, assuming 2 years needle retention (Ewers and Schmid 1981).

Further details of all functions and models used for *in situ* biomass estimations can be found in Gonzalez-Benecke et al. 2010, 2011 and 2015.

From this TAB the user can also:

- Start a new simulation, by clicking button “**Go To Inputs**” in cell I5.
- Print a Report, by clicking button “**Print Report**” in cell I11.
- Go to annual outputs report, by clicking button “**Go To Annual Outputs**” in cell I15.





### **Biomass annual outputs:**

The tab called “**summary\_biomass**” is shown as additional information after clicking the button “**Go To Annual Outputs**” in tab “**report\_biomass**”.

In this tab, a detail of yearly outputs of *in situ* biomass (ton/acre) from simulation starting age to rotation age is displayed for each species simulated. *In situ* biomass values that are displayed in this report are: Age (years), Stemwood, Bark, Foliage, Branch, Coarse Root (Tap + Laterals), Fine Root, Forest Floor Needles, Forest Floor Branches, Understory, Standing Dead Trees, Crown Residues of Thinned Trees and Coarse Root Residues of Thinned Trees.

From the tab “summary” the user also can:

- Start a new simulation, by clicking button “**Go To Inputs**” in cell **A2**.
- Go to *In Situ* biomass report, by clicking button “**Go To *In Situ* Biomass Report**” in cell **A6**.



## REFERENCES.

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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.

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C.A. Gonzalez-Benecke, 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.

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