Tree development and biomass allocation stochastic modelling: the case of Teak

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The teak's shoots have marked endogenous periodicity and cessation of extension (rhythmic growth). Then, the number of organs produced varies with the annual seasonality and among the individuals.
Using the GreenLab FSPM approach, based on the source –sink relationships at organ level, we introduce a stochastic biomass production model in the Teak development dynamics.

Experimental data

The site of study is the Agbavé forest station (0 ° 45 'E, 6 ° 43' N) in southwestern Togo (1100 mm and 1400 mm per year, with a peak in June). There are two dry seasons, one from November to March and the other from July to September.
Plant material: The analyzed teaks (*Tectona grandis* Linn f., Lamiaceae) have from one-year-old to seven-year-old (6 to 12 individuals per age). The architectural unit of teak is compound of 4 categories of axis (main stem, branches, branchlets and twigs), each characterized by distinctive morphological, physiological and functional features. The shoot growth is rhythmic and polycyclic.
Measurement method: Trees were described at Growth Unit (GU) scale (Fig. 1).
Development parameters calibration: Plant topology was recorded through MTG formalism (Godin and Caraglio, 1998). The phytomer number, length, the GU rank of annual shoot (AS) and the presence of branches were recorded for each AS.
Sink-source parameters calibration: The length, median diameter, internode dry mass and leaf dry mass per GU were recorded.

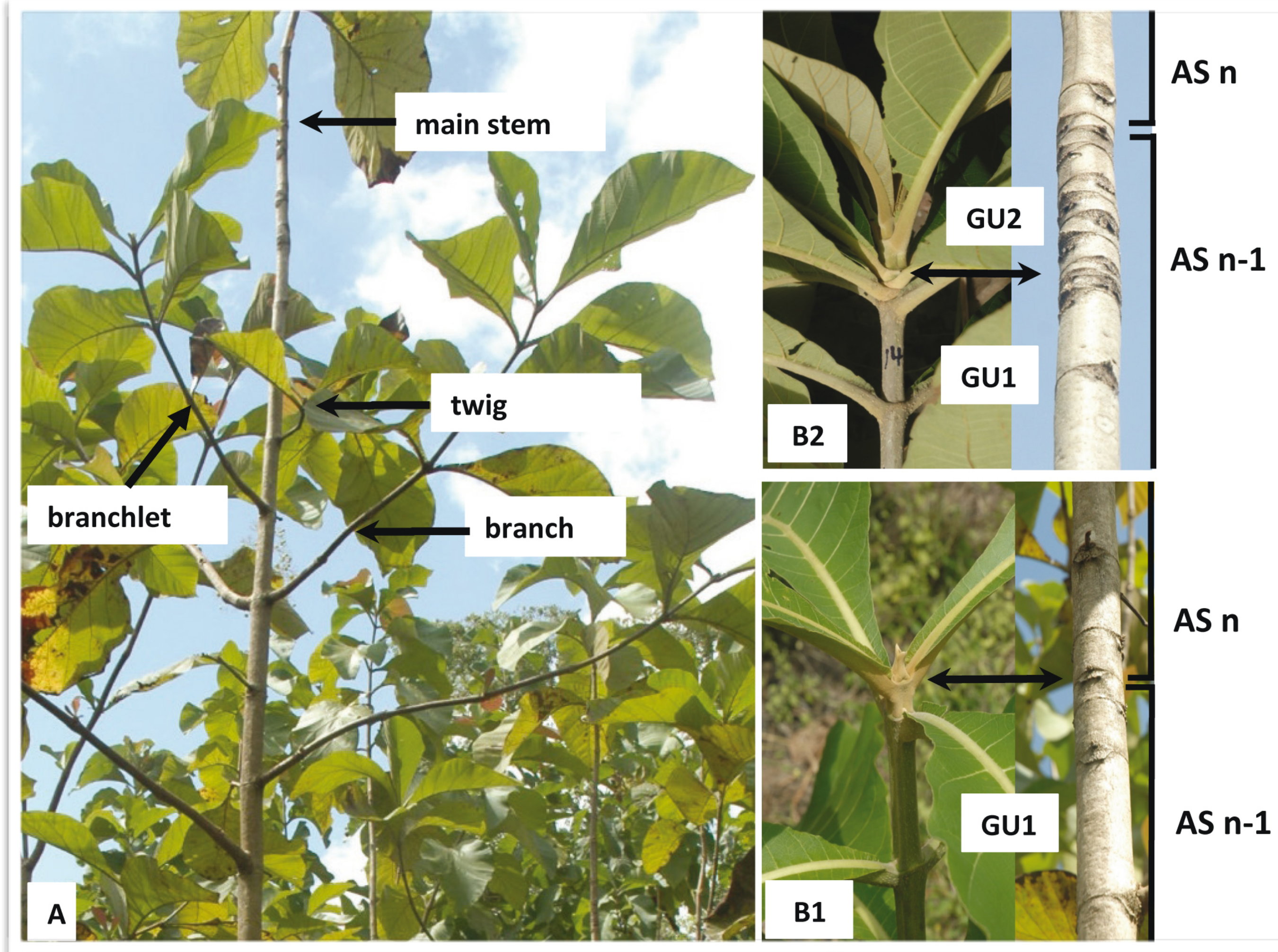

Fig. 1. Morphology of 5-years-old Teak. A: structures of the 4 axis categories; B : morphology markers of rhythmic growth : B1 : inter-annual growth cessation phase and delimitation of successive annual shoot (AS); B2: intra-annual growth cessation phase and delimitation of successive growth unit (GU).

Modeling process

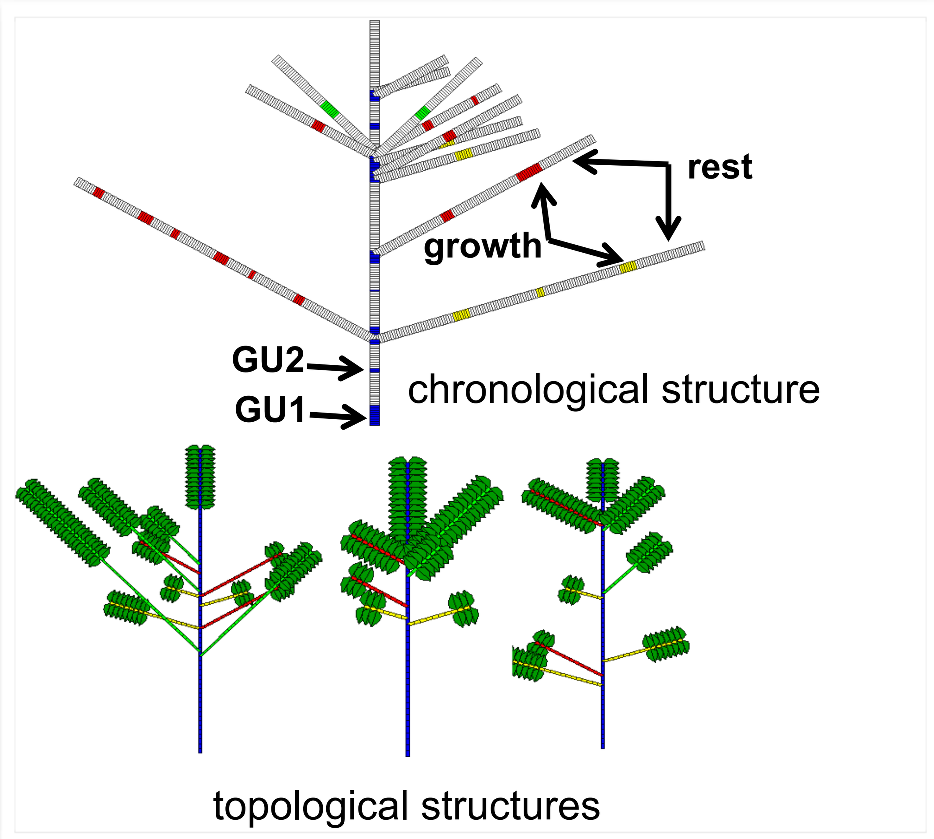

Fig. 2. Stochastic topological structure from the chronological structure in five-years-old teak. The stochastic constructions are simulated by the botanical automaton those rules are issued from development data. Main stem (blue), branche (green), branchlet (red) and twig (yellow).

Development parameters calibration: The phytomer stochastic production resulting from meristem activity is modelled by a Bernoulli process (de Reffye et al. 2012). In the teak, we show that the number of phytomer per GU distribution fits a negative binomial law with a shift of 3 phytomers corresponding to the preformed GU part . The cessation of meristem activity is controlled by the parameters (k, b) of the negative binomial law (Fig. 2). The branching probability decreased from the main stem to the short branch.
Sink-source parameters calibration: Light interception, biomass production and biomass partitioning among competing organs, including the secondary growth, are evaluated according to the GreenLab model assumptions (Cournède et al. 2011). Technically, both development and growth parameter observed organic series are fitted to the theoretical series, using a non linear least square estimator.

Results

The total functioning leaf area (Sp), high during the juvenile phase, decreases during the establishment phase and increases with the crown extension (Fig. 3).
The organ biomass allocation, mostly low over the tree establishment phase, increases proportionally to the crown area as does the growth ring allocation (Fig. 4). Afterward, the biomass rate reaches a threshold and becomes constant.
Using the estimated parameters and adding geometrical characters (mainly angles), the simulation enables the Teak tree architecture full 3D simulation including the secondary growth (Fig. 5).

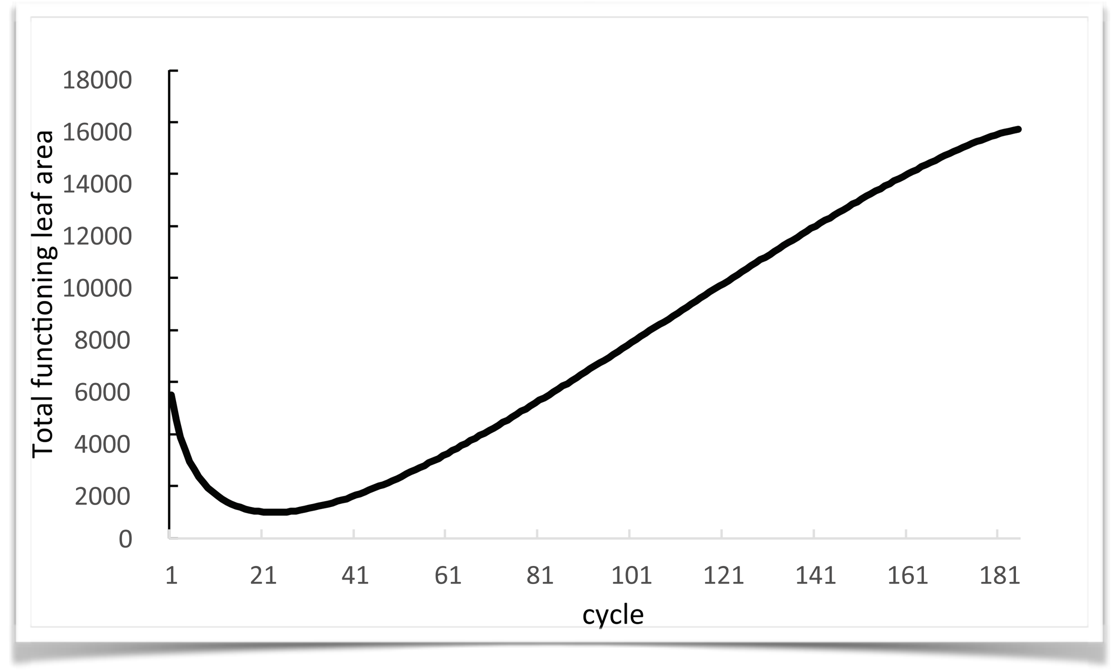

Fig. 3. The total functionning leaf area (cm^2) according to the development cycle in 5-years-old Teak.

Fig. 5. Observed and simulated with stochastic topology 5-years-old teak; Gloups software (de Reffye, CIRAD).

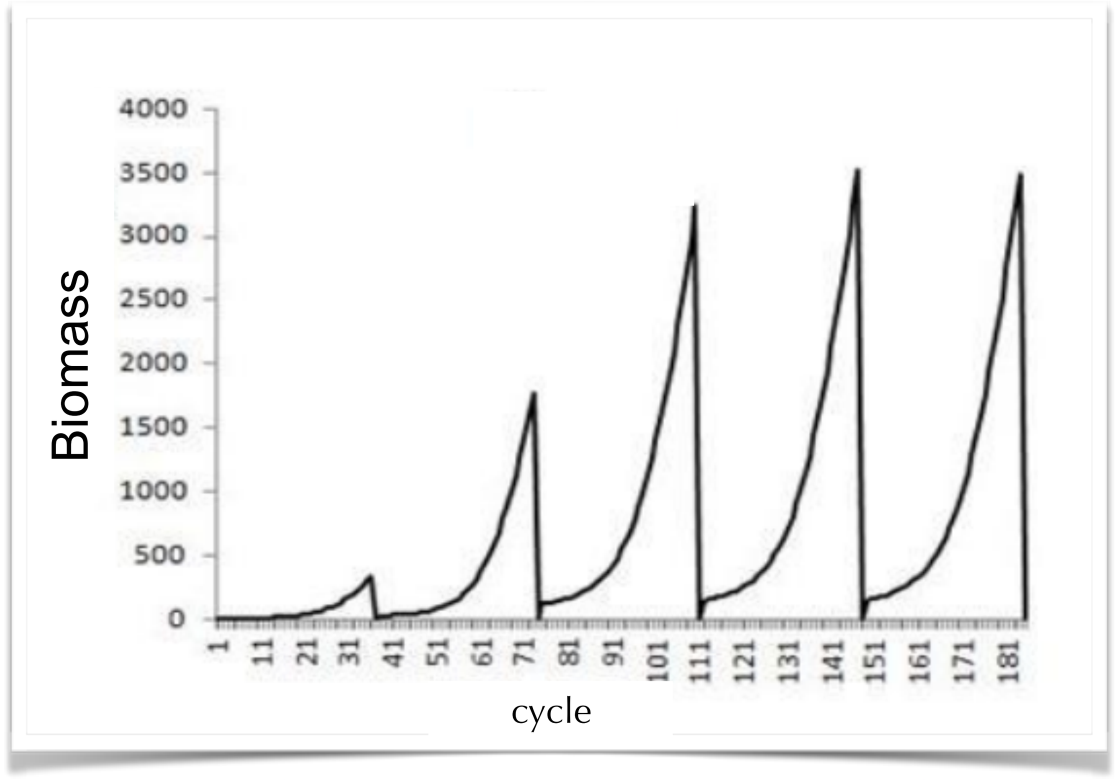

Fig. 4. Evolution of the biomass of growth ring during the first five years in Teak's main stem.

References

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Godin C and Caraglio Y, 1998. A multiscale model of topological structures. Journal of Theoretical Biology 191: 1-46.
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Conclusions and perspectives

- Teak's stochastic development with pre- and neoformed growth units and polycyclic growth was in the GreenLab Model.
- The evolution of total functionning leaf area (Sp) was fitted for the crown extension in Teak.
- The knowledge of hidden parameters estimation, strongly linked to the tree architecture allows quantitative key insigths comparisons, helpful for develop teak ideotypes definitions.
- In future, we plan to introduce the variability of wood density in the model and calibrate the model for older trees.