Toward a functional-structural model of oil palm accounting for architectural plasticity in response to planting density.

Raphael P. A. Perez, Rémi Vezy, Loïc Brancheriau, Frédéric Boudon, Doni Artanto Raharjo, Jean-Pierre Caliman, Jean Dauzat

Toward a functional-structural model of oil palm accounting for architectural plasticity in response to planting density

Raphaël P.A Perez[1], Rémi Vezy[2], Loïc Brancheriau[3], Frédéric Boudon[1], François Grand[2], Doni Artanto Raharjo[4], Jean-Pierre Caliman[4] and Jean Dauzat[2]

[1]CIRAD, UMR AGAP, F-34398 Montpellier, France.
AGAP, Univ Montpellier, CIRAD, INRAE, Montpellier SupAgro, Montpellier, France.
[2]CIRAD, UMR AMAP, F-34398 Montpellier, France.
AMAP, Univ Montpellier, CIRAD, CNRS, INRAE, IRD, Montpellier, France
[3]CIRAD, UPR BioWooEB, F-34398 Montpellier, France.
BioWooEB, Univ Montpellier, CIRAD, CNRS, INRAE, IRD, Montpellier, France
[4]Sinar Mas Agro Resources Technology Research Institute (SMARTRI), Libo Estate, Kandis, Pekanbaru, Riau, Indonesia

For correspondence: raphael.perez@cirad.fr

Keywords: FSPM, Lidar, phenotypic plasticity, plant architecture, planting density

Abstract

Functional-structural plant modelling approaches (FSPM) open the way for exploring the relationships between the 3D structure and the physiological functioning of plants in relation to environmental conditions. FSPMs can be particularly interesting when dealing with perennial crops like oil palm, for which research on innovative management practices requires long and expensive agronomic trials. The present study is part of the PalmStudio project, which aims at developing a FSPM for oil palm capable of conducting virtual experiments to test the relevance of innovative management practiceds and/or design ideotypes.

We propose a methodological approach which integrates architectural responses to planting density in an existing oil palm FSPM (Perez *et al.* 2018a b). Combining standard field phenotyping with Lidar-based derived measurements, we manage to evaluate the phenotypic plasticity of the main parameters required for the calibration of the 3D plant model. LiDAR scans were processed using the PlantScan3D software (Boudon et al. 2014) to derive phenotypic traits of leaf geometry that were compared to labour-intensive measurements. Density-based allometries of leaf geometry and biomass are then derived from the observed variations in phenotypic traits and integrate into the FSPM.

Our results illustrate the accuracy and the efficiency of Lidar-based phenotyping of leaf geometrical traits. In average, we find less than 3% of difference in leaf dimensions (i.e. rachis length) in comparison with traditional hand-made field measurements. The fast and efficient measurements of usually labour-intensive traits such as leaf curvature allowed estimating the plasticity of leaf geometry in response to density. We find that the main traits affected by density were leaf dimensions (up to 15% and 25% of increase in rachis length and petiole length respectively) and curvature (15% of increase in leaf erectness-related parameter), whereas other structural traits like the number of leaflets per leaf remained unchanged. Simple density-based allometric relationships were then modelled and combined with the existing allometric-based 3D oil palm model VPalm (Perez *et al.* 2018a). These data also enable the development and the integration in VPalm of a biomechanical model simulating leaf curvature.

The methodology presented in this study paves the way for a rapid integration of phenotypic plasticity in FSPMs. Our FSPM is now able to estimate how planting density affect not only plant architecture but also functional processes such as carbon assimilation and transpiration. Ongoing research aims at coupling the current FSPM with a carbon allocation model (Pallas *et al.* 2013) to simulate the retroactions of functioning processes on plant architecture together with environmental and agronomic conditions.

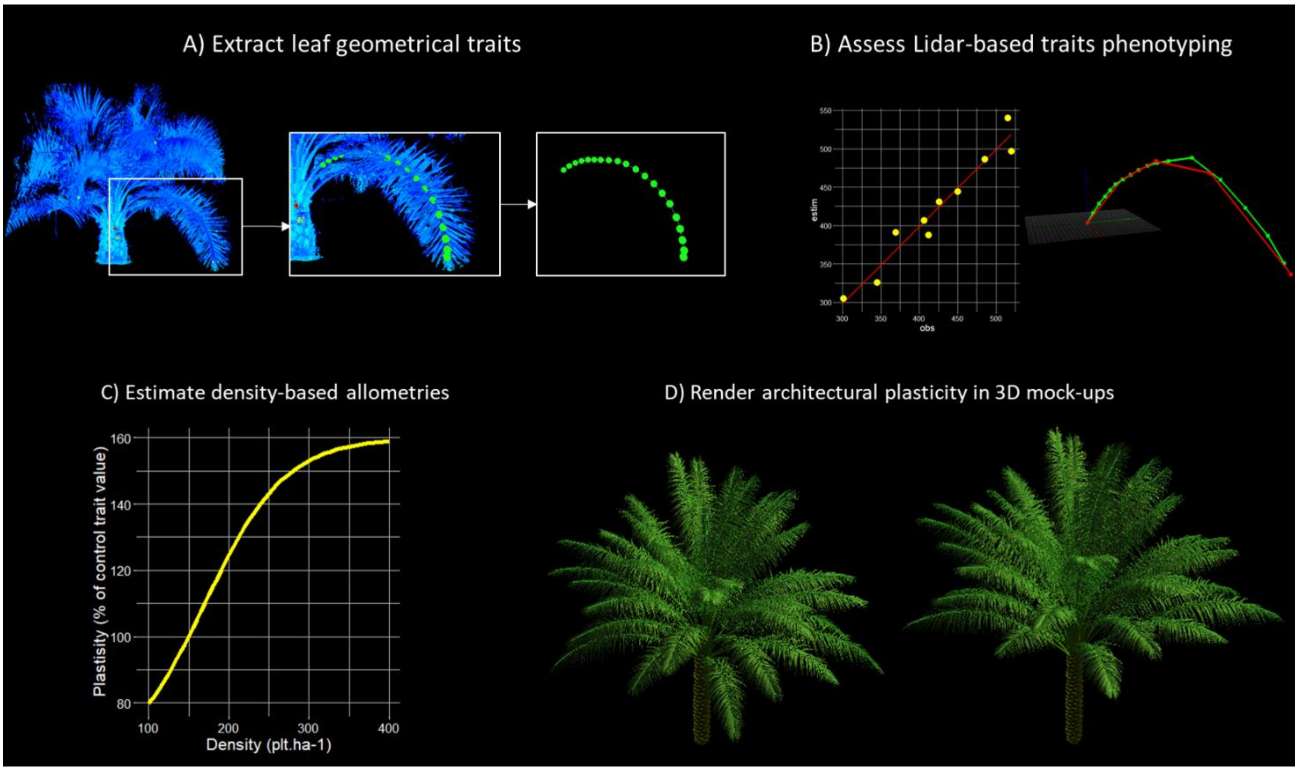

Figure: Overview of the methodological approach proposed to integrate in a 3D model the effect of planting density on plant architecture. A) Lidar point clouds with the extraction of leaf geometrical attributes (length and curvature). B) Comparison of Lidar-based vs hand-measured rachis length (left) and 3D positions for leaf curvature estimation (right). C) Example of density-based allometry. D) 3D model outputs for conventional (left) and double (right) density.

References

Boudon F., Preuksakarn C., Ferraro P., Diener J., Nacry P., Nikinmaa E., Godin C. (2014) Quantitative assessment of automatic reconstructions of branching systems obtained from laser scanning. *Annals of Botany*, **114** (4), 853-862.

Pallas B., Clément-Vidal A., Rebolledo M.-C., Soulié J.-C. & Luquet D. (2013) Using plant growth modeling to analyze C source-sink relations under drought: inter- and intraspecific comparison. *Frontiers in plant science* **4**, 437.

Perez R.P.A., Costes E., Théveny F., Griffon S., Caliman J.P. & Dauzat J. (2018a) 3D plant model assessed by terrestrial LiDAR and hemispherical photographs: A useful tool for comparing light interception among oil palm progenies. *Agricultural and Forest Meteorology* **249**, 250–263.

Perez R.P.A., Dauzat J., Pallas B., Lamour J., Verley P., Caliman J.P., … Faivre R. (2018b) Designing oil palm architectural ideotypes for optimal light interception and carbon assimilation through a sensitivity analysis of leaf traits. *Annals of Botany* **121**, 909–926.