

Using Virtual Plants for Upscaling Carbon Assimilation from the Leaf to the Canopy Level. Application to Coffee Agroforestry Systems

J. DAUZAT¹, N. FRANCK², P. VAAST¹

¹Centre de Coopération Internationale en Recherche Agronomique pour le Développement,
Montpellier, France

²Facultad de Ciencias Agronómicas, Universidad de Chile, Santiago, Chile

SUMMARY

Models of carbon assimilation are regularly developed at the leaf scale and must be afterwards integrated at the canopy scale. Analytical methods for this integration imply several simplifying assumptions and, in complex cases like coffee agro-forestry systems, face the difficulty of a proper assessment of the actual light interception by coffee plants. Alternatively, the ARCHIMED method of numerical integration proposed in this study allows simulating the irradiation of individual leaves within any 3D virtual stand. With this information, carbon assimilation models can be properly integrated from leaf to canopy scale. Moreover, the energy balance can be solved to output the temperature of leaves which can be subsequently accounted for the calculation of their assimilation. A comprehensive carbon assimilation model was developed for coffee leaves under different growth irradiances by Franck et al. (ASIC, 2006). In order to accurately upscale this model at canopy level, virtual 3D canopies were reconstructed from field digitizing of shaded and unshaded coffee plants. These virtual canopies were then used to simulate the carbon assimilation (An) of coffee in pure stand or within agroforestry systems. Results revealed assimilation potentialities of the shaded coffee stand comparable to that of the unshaded canopy because of its higher LAI. In contrast the unshaded canopy assimilation was strongly hampered by branch defoliation attributed to an excessive fruit load. Sensitivity analyses demonstrated that the photoinhibition effect is negligible during the rainy season and of secondary importance during the dry season prevented leaves are acclimated to high irradiances. On the contrary, excessive leaf temperature is the major reducing factor of An during the dry season and/or in lowlands. These results illustrate the particular interest of agroforestry systems in warm and dry conditions. Through these simulation experiments, the carbon assimilation potentialities of coffee orchards can be assessed vs. the climatic conditions and the shading rate of the above tree strata. Recommendations can then be driven regarding the optimal density of trees according to their crown development as well as the expected gain of An resulting from tree pruning.