J10.2 Coupling a 3D Light Interception with a Growth and Yield Model to Adjust Shade Level in Coffee Agroforestry Systems Simulated under Climate Change

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Arches (Sheraton Salt Lake City Hotel)

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Recorded Presentation

Many agronomic systems could be at risk considering the shorter-term climate changes but several effects and interactions are still uncertain. Process-based models (PBMs) are generally well suited for predictions under new conditions but their complexity causes high computational demand which limits their application. This is particularly true for complex multi-layer or agroforestry systems requiring plant-scale simulations in 3D. An alternative is to summarize their outputs in statistical models called metamodels, which can be used afterwards rapidly in a prediction mode. These metamodels also 1) allow to understand better the processes within the source model (uncertainty and sensitivity analysis) and 2) can be used for coupling different spatial or time scales models.

Coffee growth and fruit production are particularly sensitive to high temperatures and water availability, and previous studies often predicts future huge loss of productions or area cover. Nevertheless, shade provided in agroforestry systems could mitigate the effects of climate changes under different management options. In this study, we modeled several management options of coffee agroforestry systems, e.g. shade tree density and species, and the use of a hybrid cultivar of coffee to estimate their suitability and provision of ecosystem services under predicted future climate changes. In Tarrazu (Costa Rica), the models for future climate (AR5, statistically downscaled) predicted an increase of air temperature, while rainfall would remain at similar levels.

Two numeric models were coupled using metamodels, a tree scale PBM (MAESPA) for extinction coefficients (diffuse and direct K) and light-use efficiency (LUE) simulations, and a plot scale PBM (GO+) for growth and yield simulations. A rating between management scenarios was then proposed by comparing canopy temperature, coffee and timber yield, carbon balance and water use of past and future coffee growth cycles, under the two contrasted RCP4.5 and 8.5 future climatic scenarios.

First results show that management could strongly impact coffee canopy temperature, light use efficiency, water use efficiency and photosynthesis, which are the main drivers of coffee plant fitness and thus coffee beans production potential. Figure 1 shows that coffee grown under shade trees had reduced mean canopy temperature (-1.22°C*** and -2.21°C*** for *E. poeppigiana* and *C. alliodora* respectively) compared to full sun management, while showing a moderate reduction of net photosynthesis (-21.6%*** and -17.8%*** resp.) thanks to an increased light use efficiency (+23.4%*** and +26.2%*** resp). Also, Coffee is particularly sensitive to maximum daily temperature, and results showed that in near future (2030-2049), all *C. alliodora* densities (i.e. 50-75-100-125 Trees.ha^{-1}) and *E. poeppigiana* 350 Trees.ha^{-1} density will be able to significantly reduce the maximum daily canopy temperature (down to -6.83°C*** in average for *C. alliodora* with 125 Trees.ha^{-1}) compared to full sun plantations on the same period (Figure 2).

Moreover, simulations showed negative maximum temperature effect on assimilation was present under full sun management only, and eventually largely compensated by positive [CO2] effect (Figure 3).

These findings could drive climate change adaptations options, as the scenarios made from the simulations will now be presented to stakeholders to assess their adoptability according to their performance.

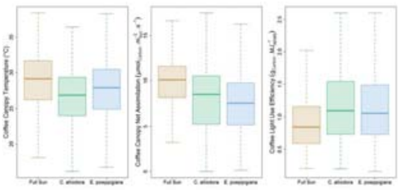

Figure 1. Shade effect (average for all shade tree densities) on -from left to right- coffee canopy temperature, canopy net assimilation and light use efficiency. *C. alliodora* and *E. poeppigiana* densities range: 50 to 125 and 200 to 400 Trees.ha-1 respectively. Results from MAESPA simulations.

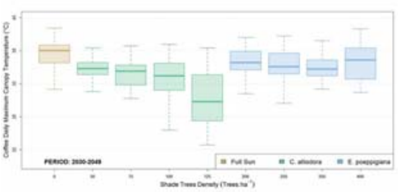

Figure 2. Mitigation of maximum daily coffee canopy temperature by shade tree density (simulations for the period between 2030 and 2049).

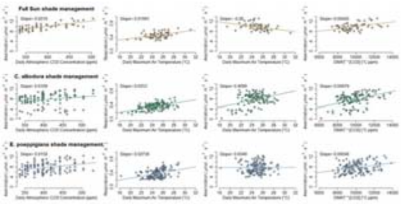

Figure 3. Effects of maximum daily canopy temperature and CO2 compensation interaction on coffee canopy assimilation and coffee canopy respiration under three shade management.

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