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Using the MAESTRA model to simulate light interactions and photosynthesis in a heterogeneous agroforestry system

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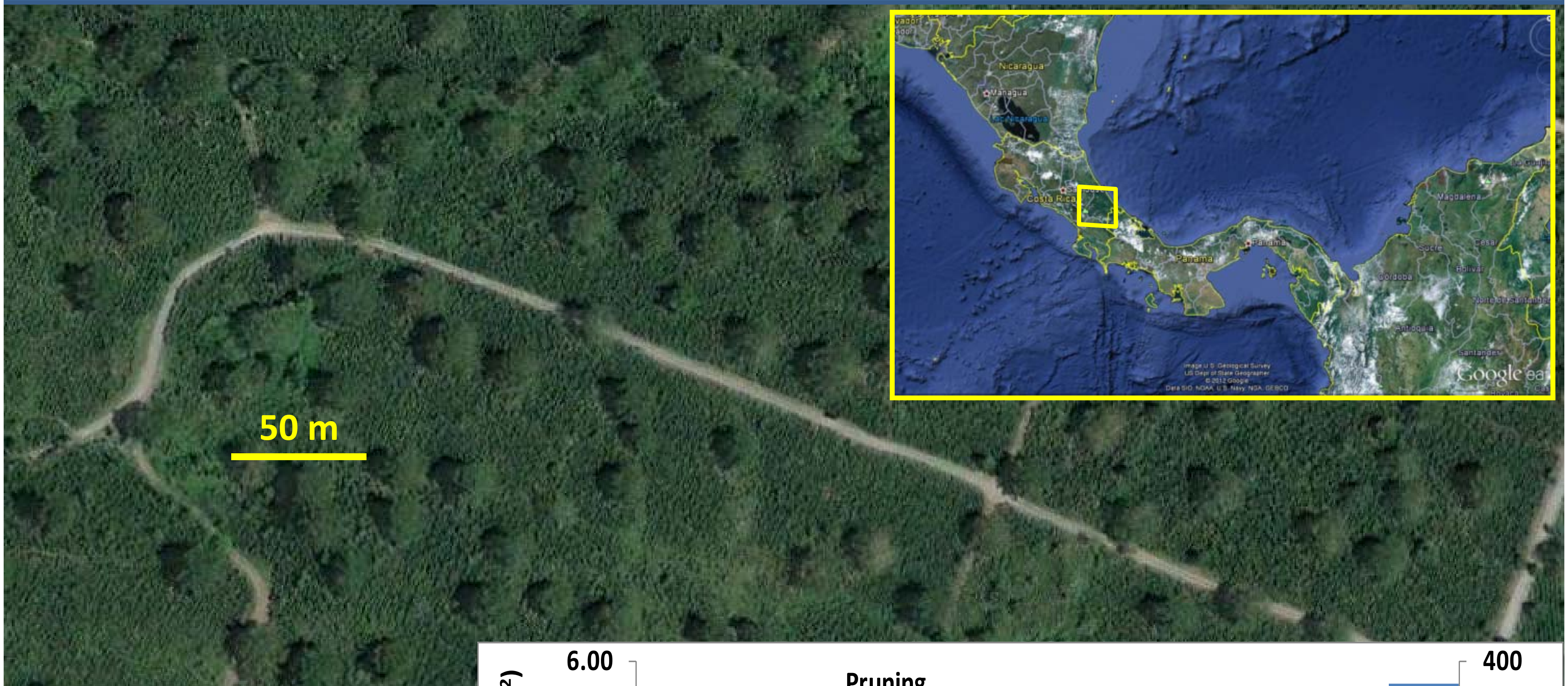
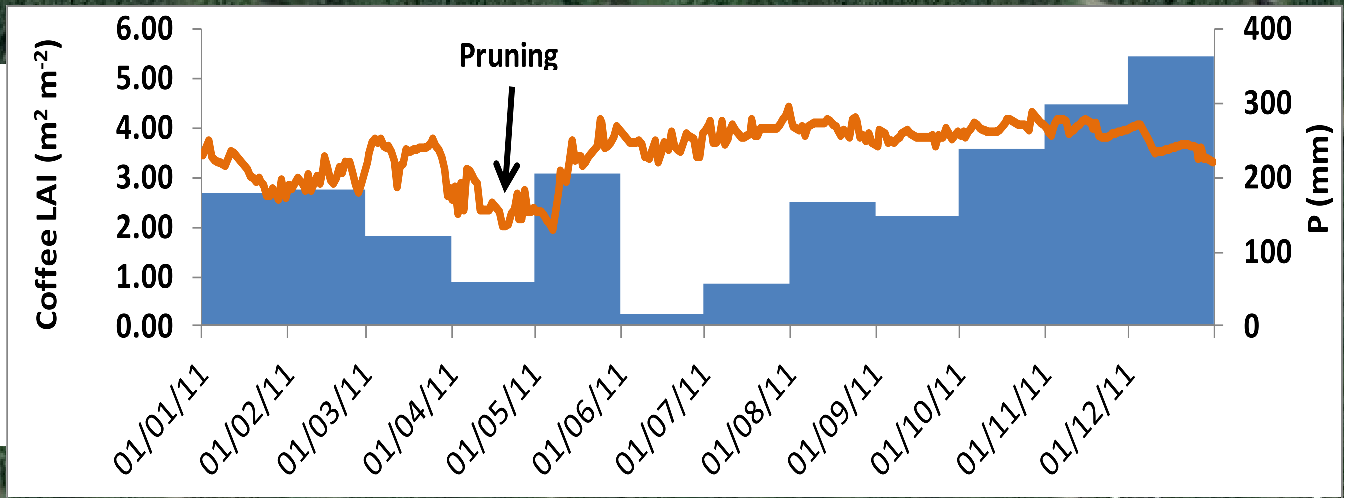
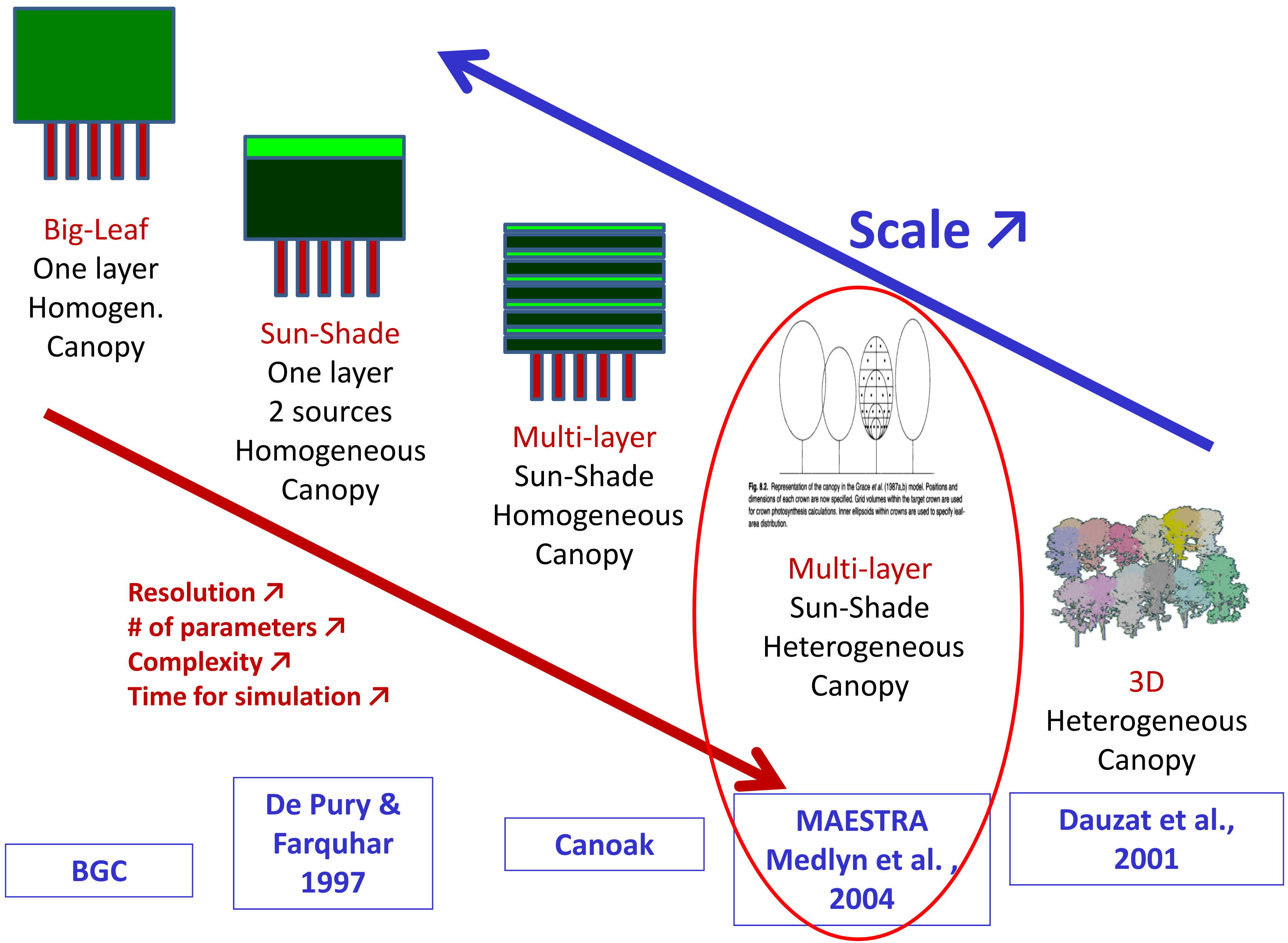
Our case study: coffee agroforestry in Costa Rica

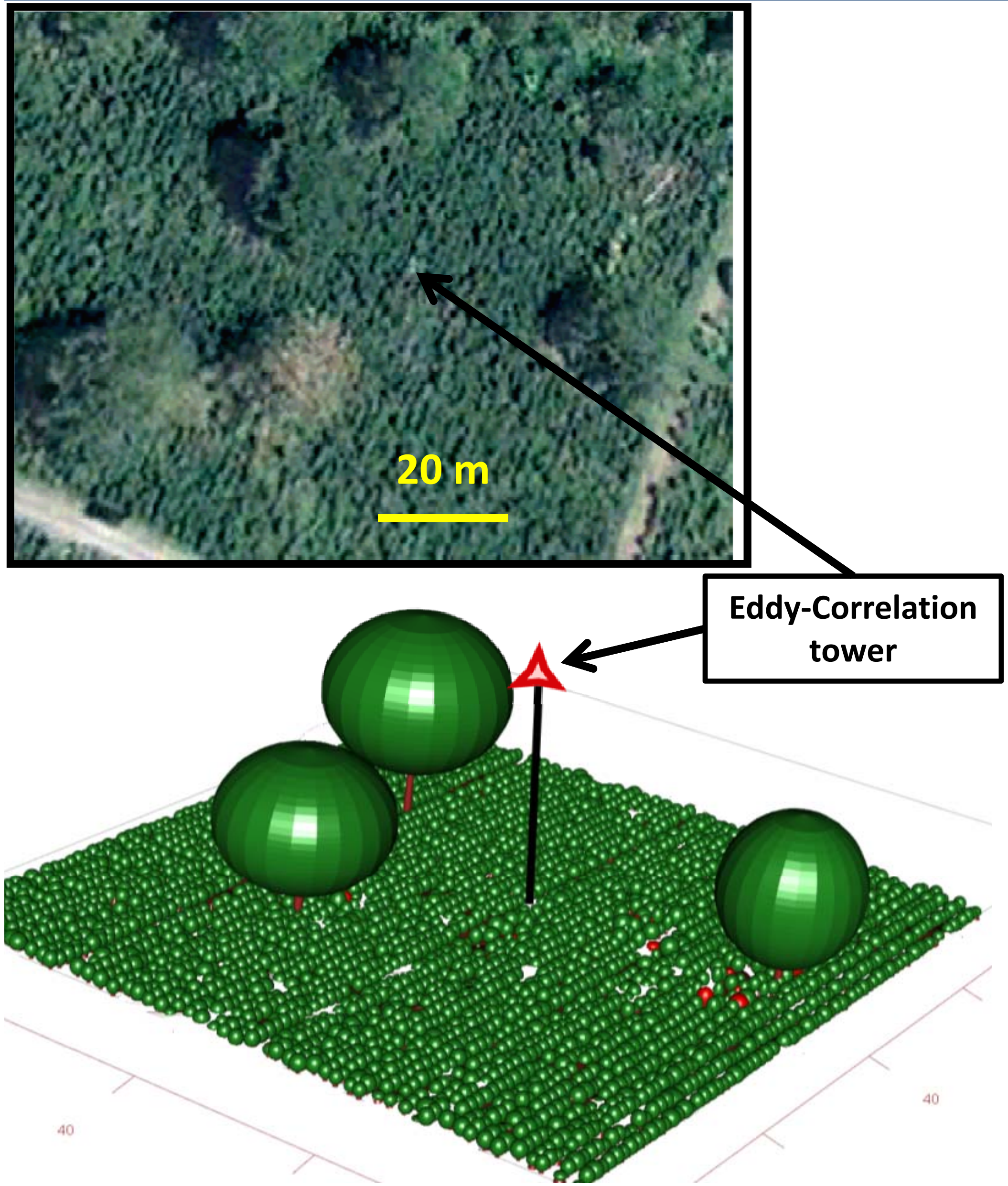


- Tropical evergreen broadleaved (EBF).
- No dry season (P=3000 mm)
- 6300 coffee plants + 15 shade trees/ha
- Annual pruning
- 2 < LAI_seasonal < 4

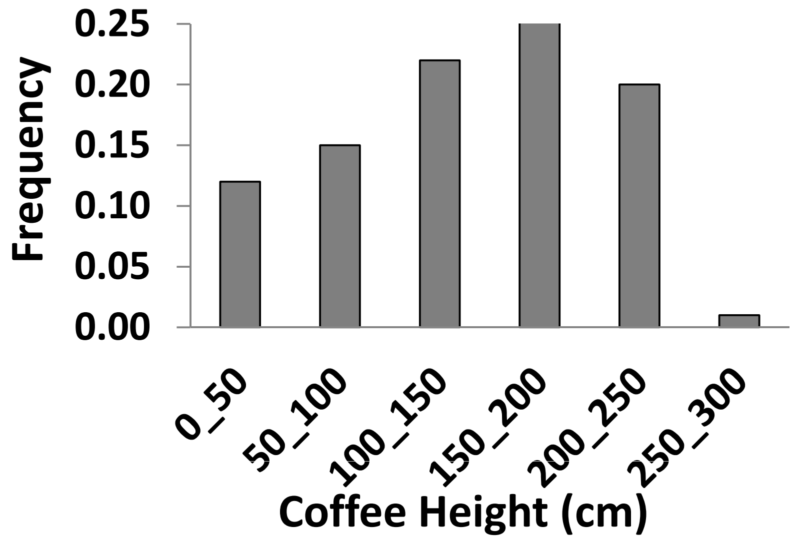


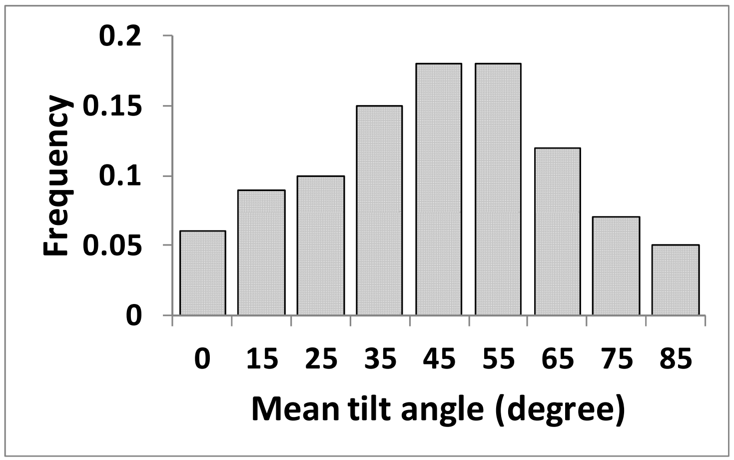

Scale ↗
Big-Leaf
One layer
Homogen.
Canopy
Sun-Shade
One layer
2 sources
Homogeneous
Canopy
Multi-layer
Sun-Shade
Homogeneous
Canopy
Fig. 8.2. Representation of the canopy in the Grace et al. (1987a,b) model. Positions and dimensions of each crown are now specified. Grid volumes within the target crown are used for crown photosynthesis calculations. Inner ellipsoids within crowns are used to specify leaf-area distribution.
Multi-layer
Sun-Shade
Heterogeneous
Canopy
3D
Heterogeneous
Canopy
Resolution ↗
# of parameters ↗
Complexity ↗
Time for simulation ↗
BGC
De Pury &
Farquhar
1997
Canoak
MAESTRA
Medlyn et al. ,
2004
Dauzat et al.,
2001

Parameterizing plot structure, leaf area density and angle



With inventories :





Physiological parameters

Farquhar et al. (1980):

$VCMAX_{ref}$ = 44 µmol m-2 s-1

$JMAX_{ref}$ = 88 µmol m-2 s-1

Rd_{ref} = 0.5 µmol m-2 s-1

Ball et al. (1987):

g0: 0.0097 mol m-2 s-1

g1: 4.6

Γ : 0.006 µmol m-2 s-1

2011 Ecosystem C Balance (tC ha^{-1} yr^{-1})

Lasslop et al., 2010

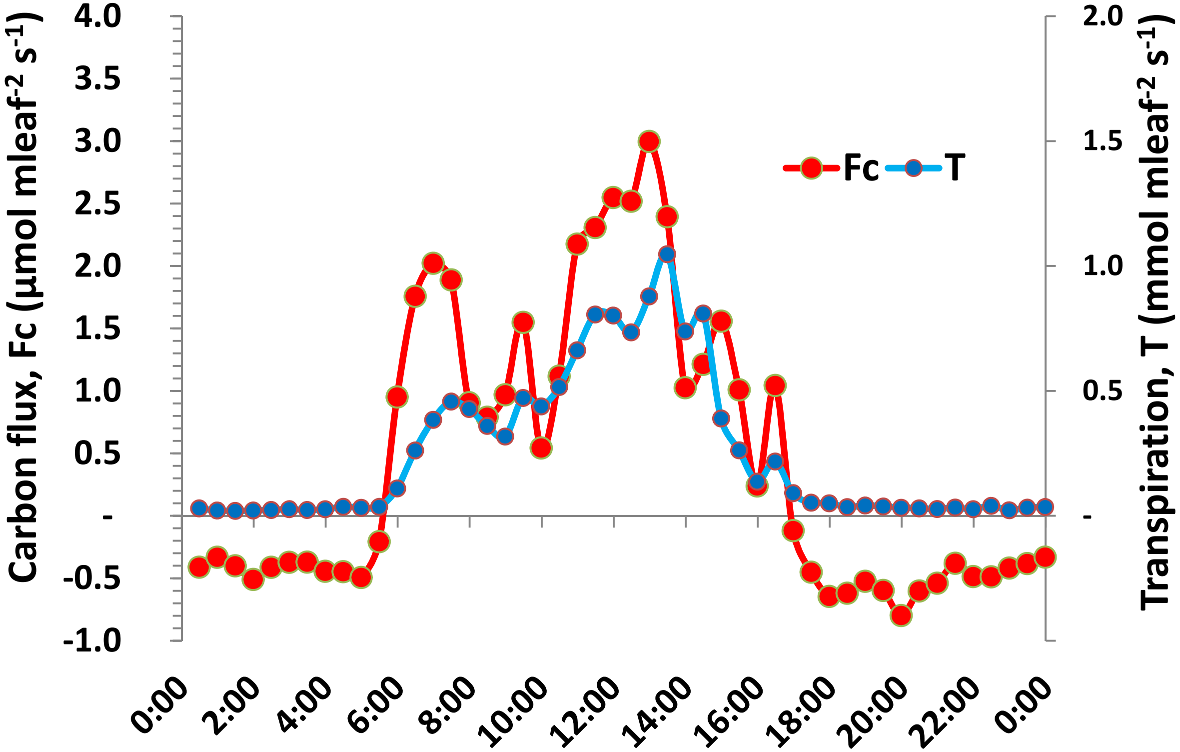
NEP =-4.1

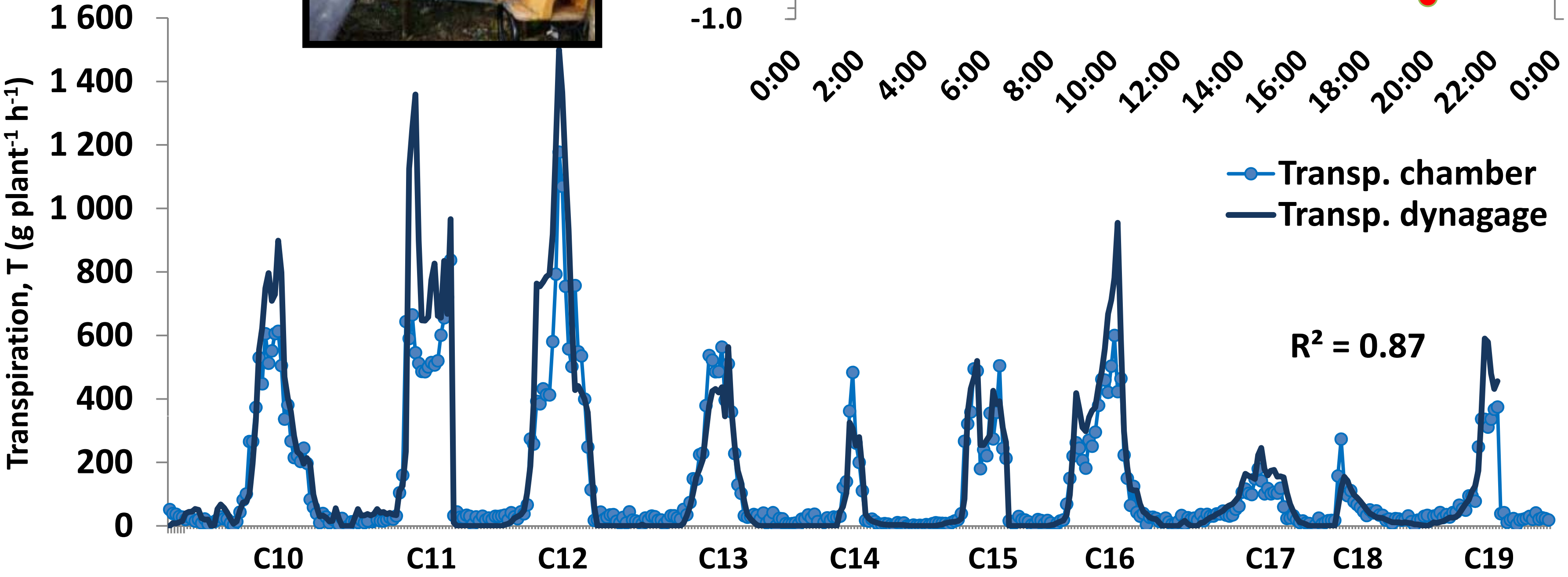
GPP=20.7

Reco = 16.6

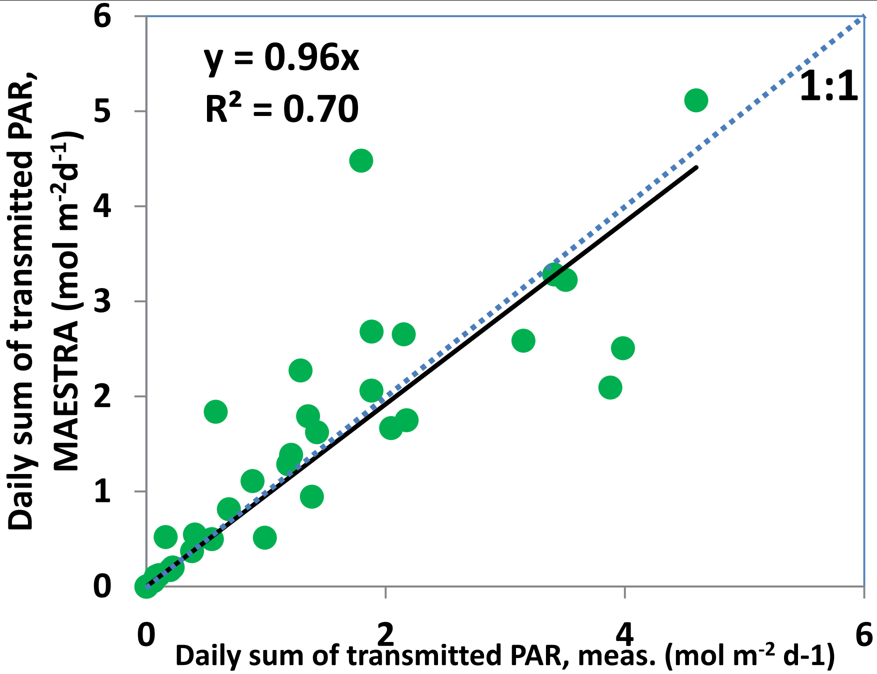
Coffee Flux webpage

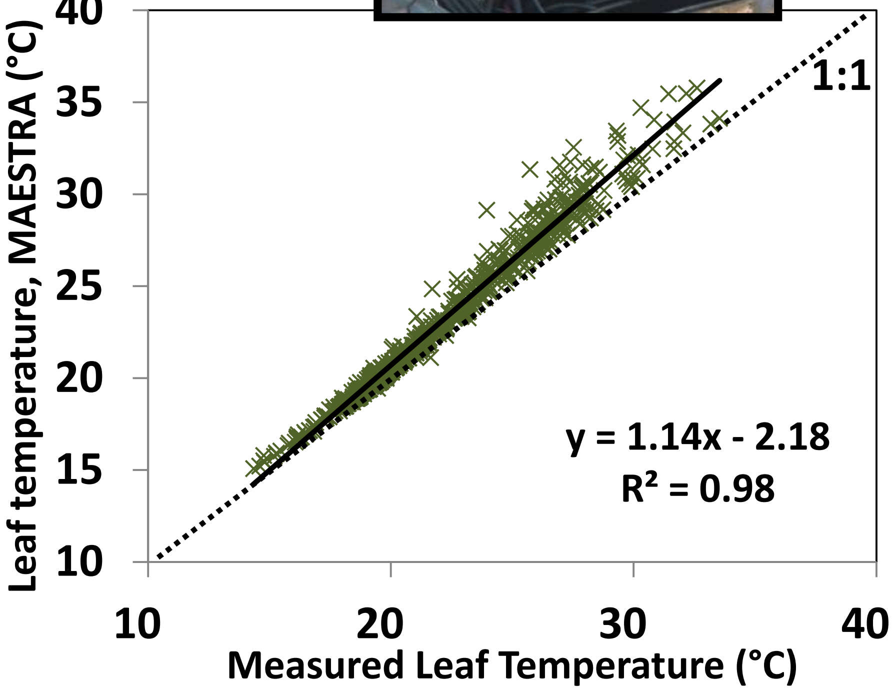
A semi-closed chamber designed to verify MAESTRA at the whole-plant scale





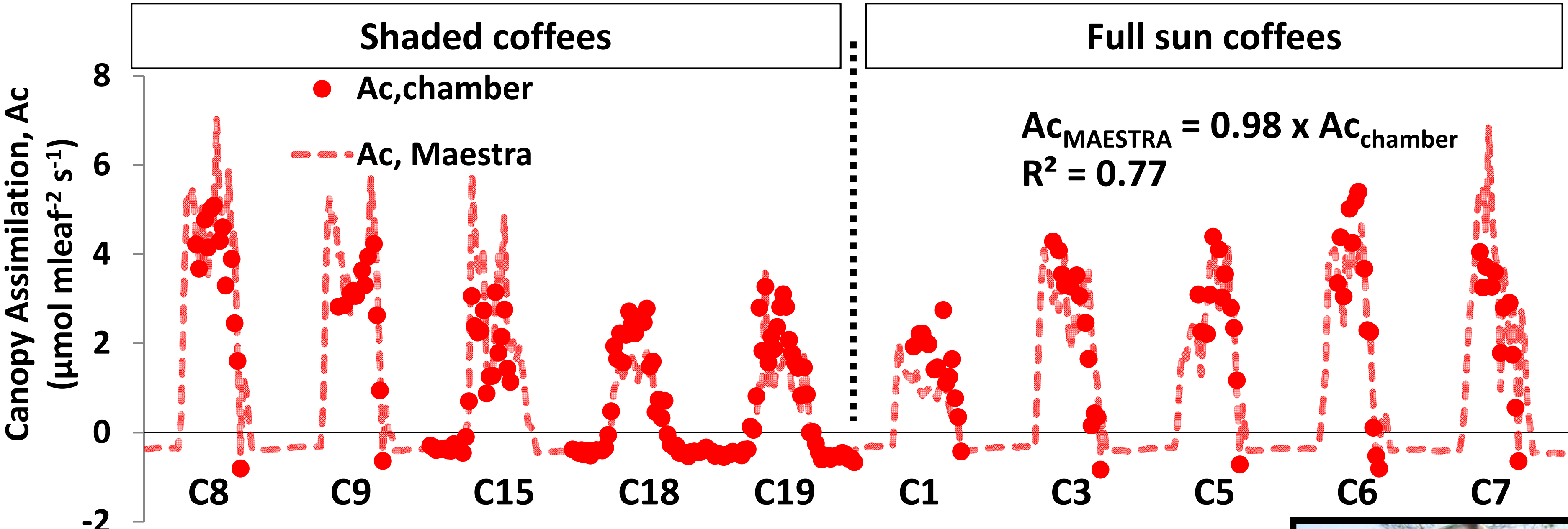
Verifying the transmitted PAR & Leaf Temperature

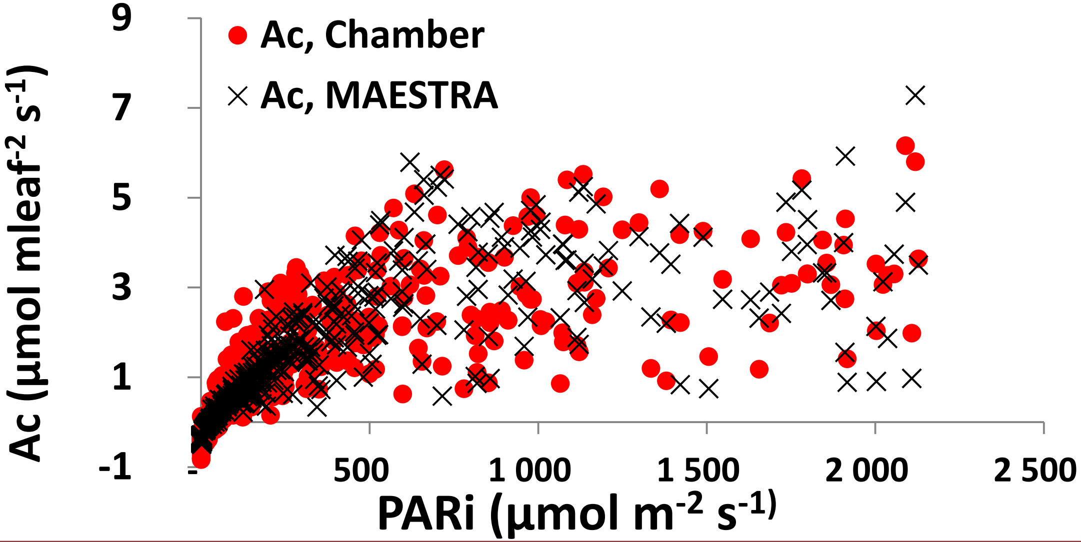




MAESTRA transmitted PAR is reliable on a daily basis. Leaf Temperature is slightly overestimated by MAESTRA indicating possible transpiration concerns.

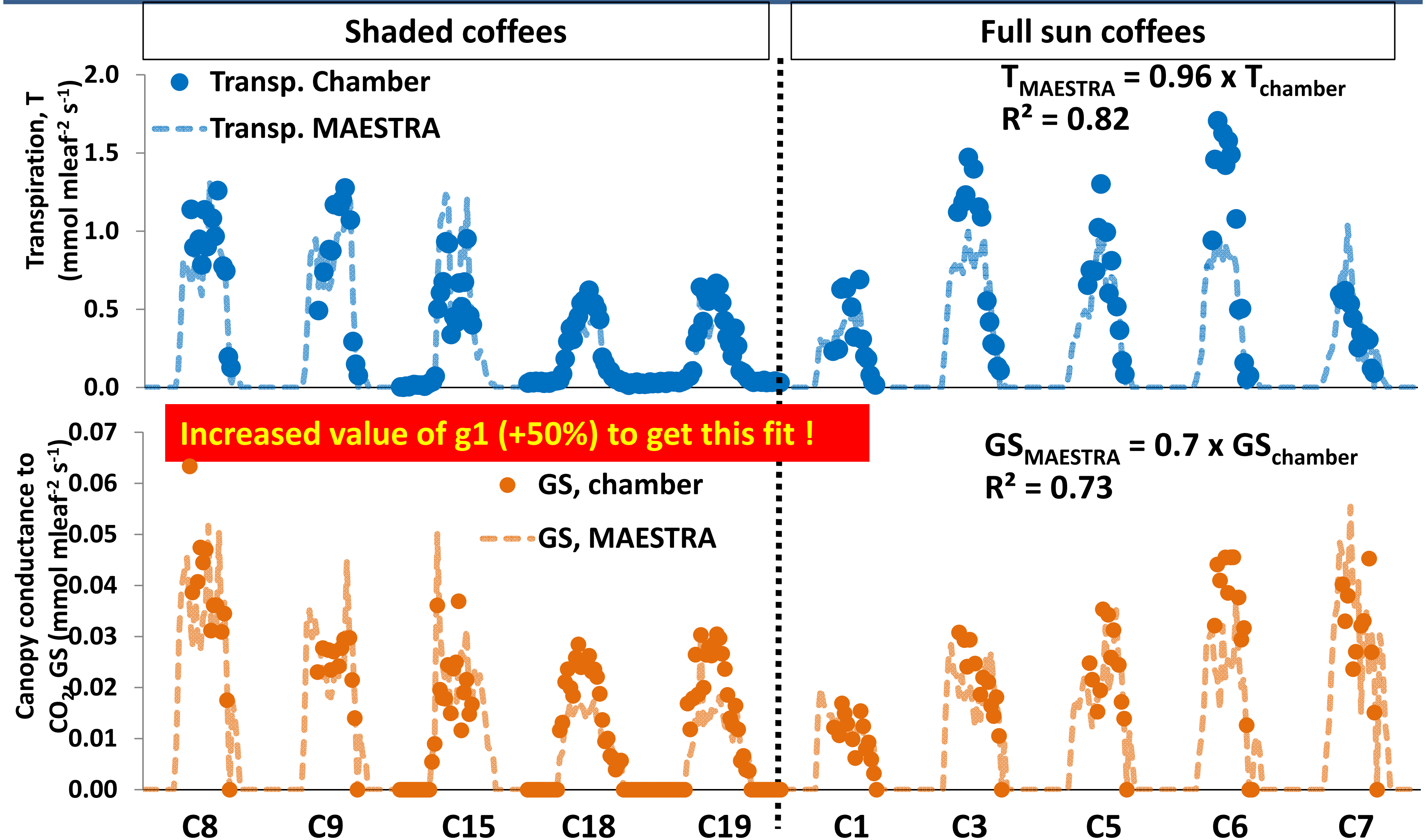
Verifying the modeled photosynthesis at plant scale





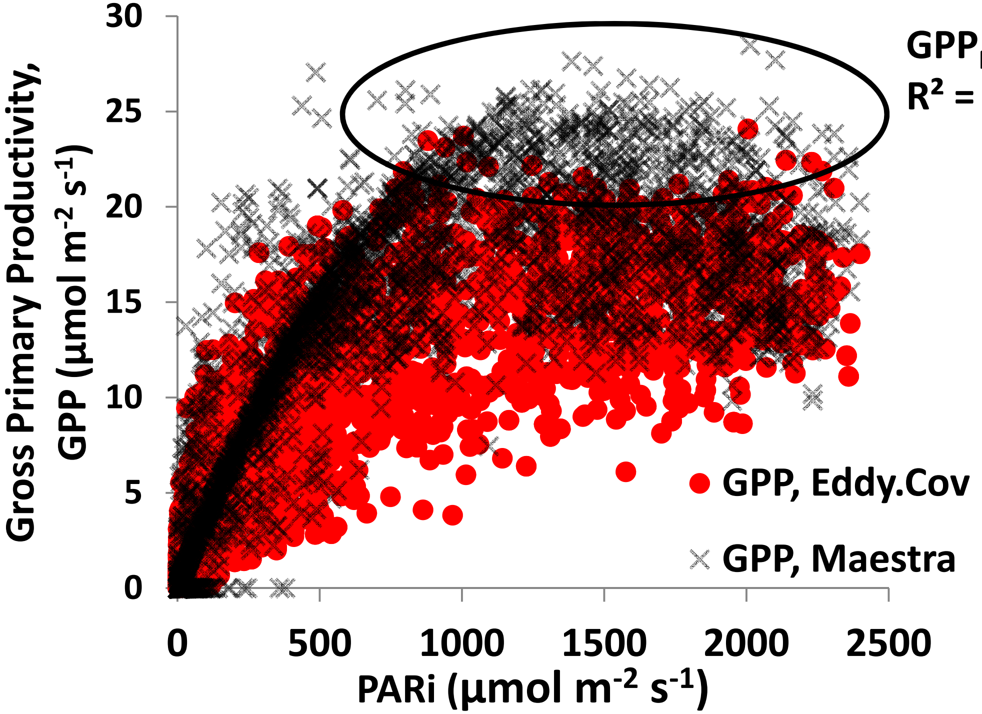
Canopy assimilation is reliably simulated by MAESTRA at plant scale

Verifying the modeled transpiration at plant scale

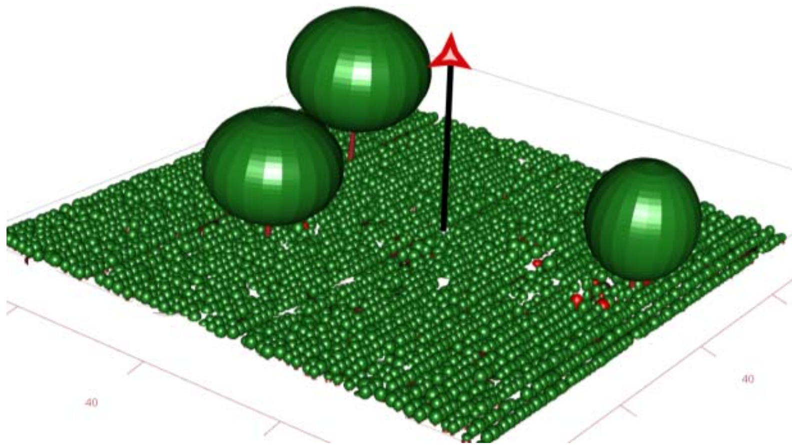


Ball et al. g1 parameter (leaf scale) was not sufficient at plant scale.
MAESTRA would underestimate slightly stomatal conductance & transpiration at plant scale?

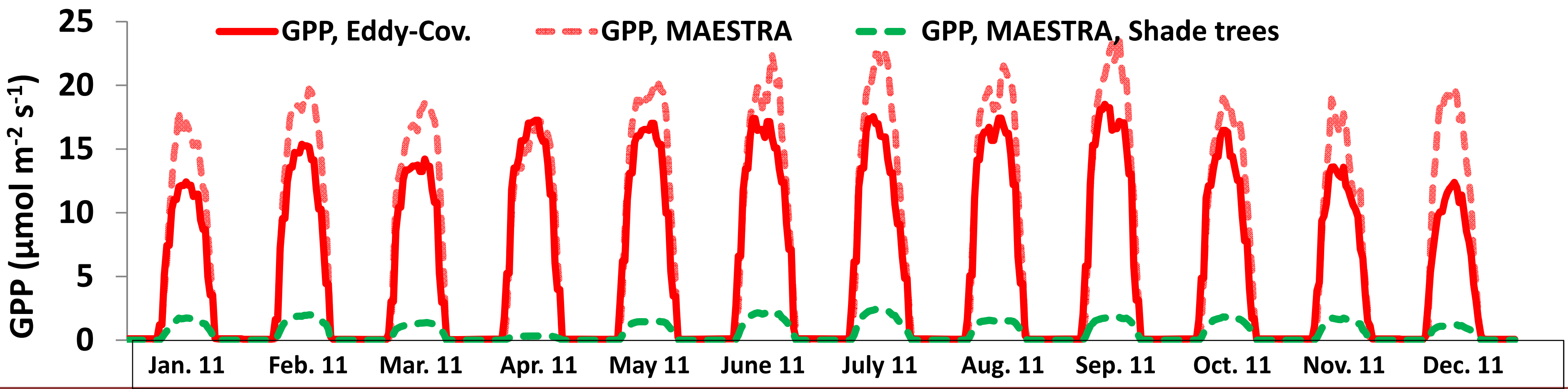
Verifying the plot photosynthesis



$GPP_{MAESTRA}$= 1.16 x GPP_{eddy} + 0.36
R^2 = 0.87

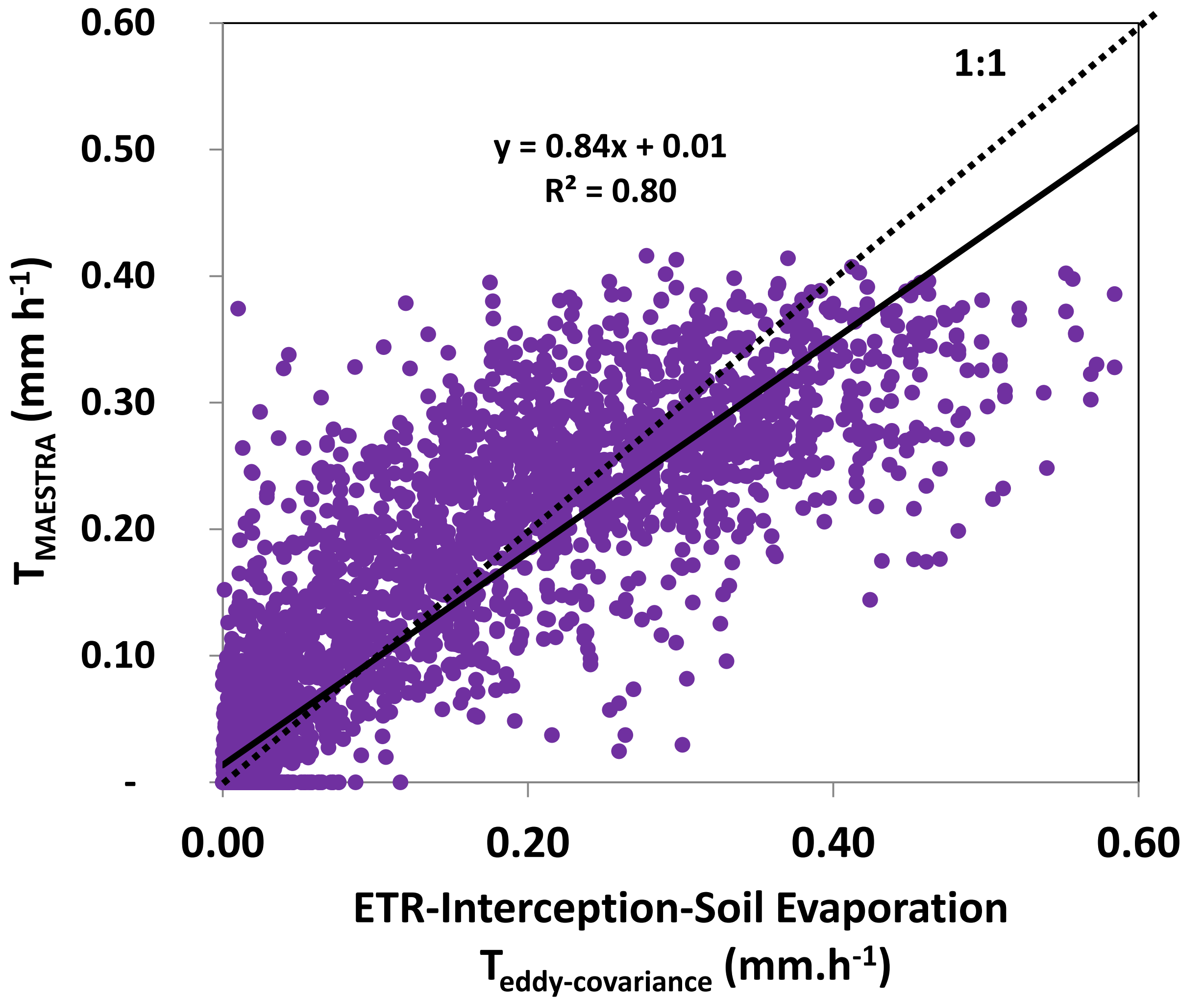


No additionnal calibration at this step



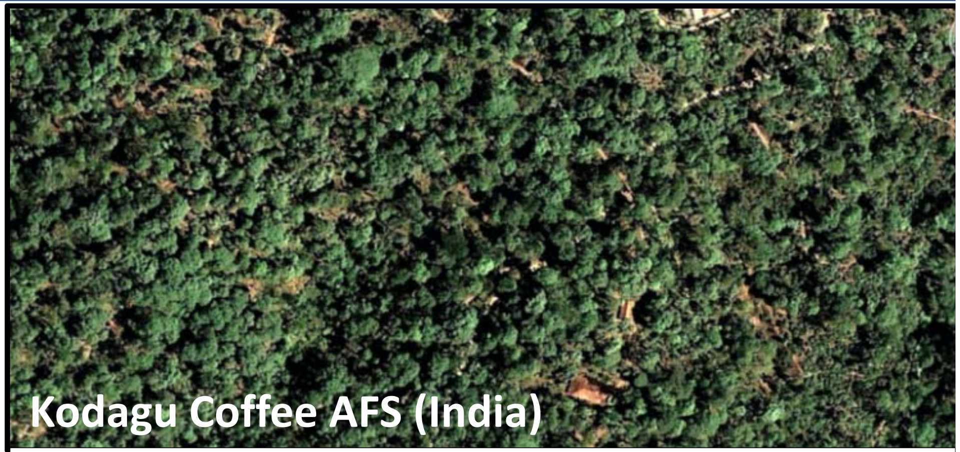
GPP seasonality is well simulated but some discrepancies remain.

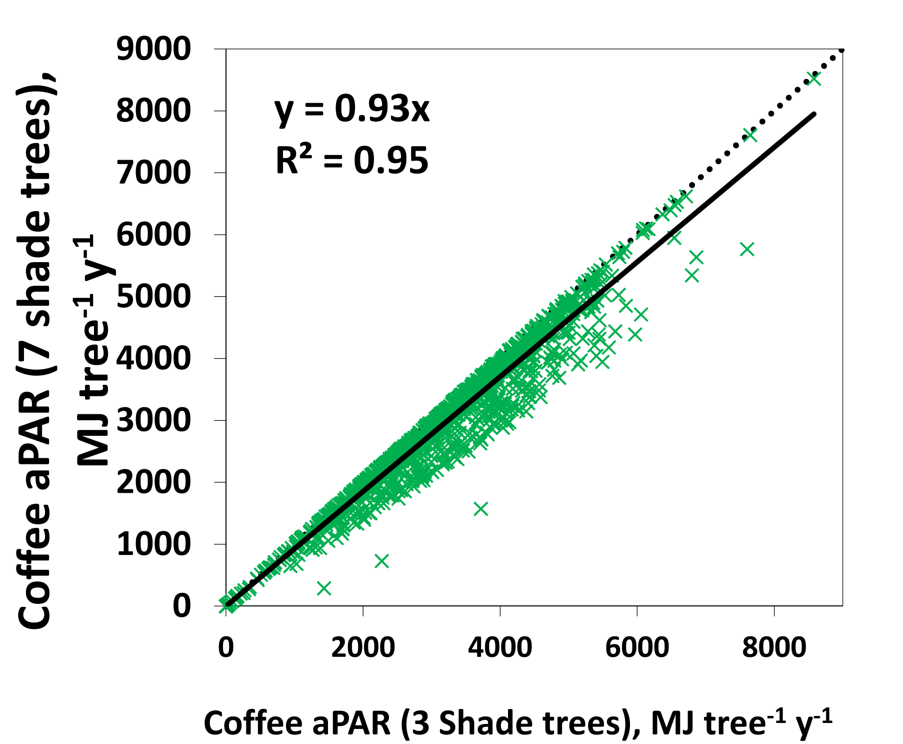
Checking the Plot Transpiration…

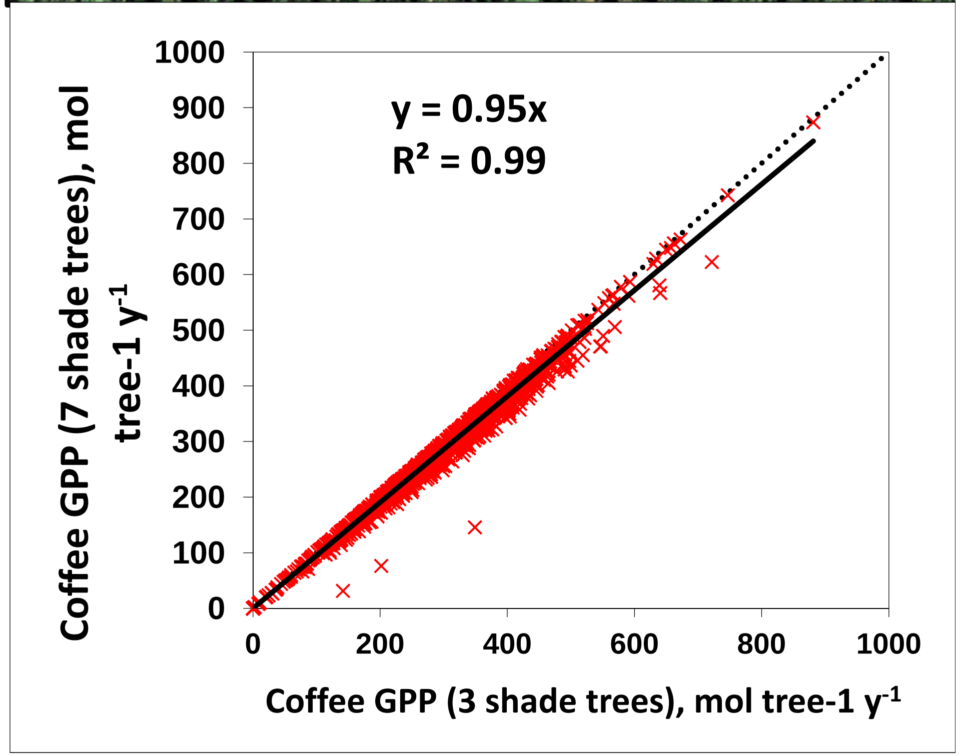


Modeled transpiration remains underestimated at plot scale.

Using MAESTRA for designing future agroforestry systems ?







Conclusions

- Agroforestry systems present complex spatial structure and interactions that gain to be addressed using array models such as MAESTRA. For instance, to improve light capture through optimized designs
- MAESTRA is a promising trade-off between Sun/Shade and 3D models for simulating AFS.
- The first simulations are encouraging but require more work on parameterization: LAD model, g1 parameter… Other MAESTRA outputs would need to be checked: WUE, Sensible Heat Flux, Absorbed net radiation.


Thank you !