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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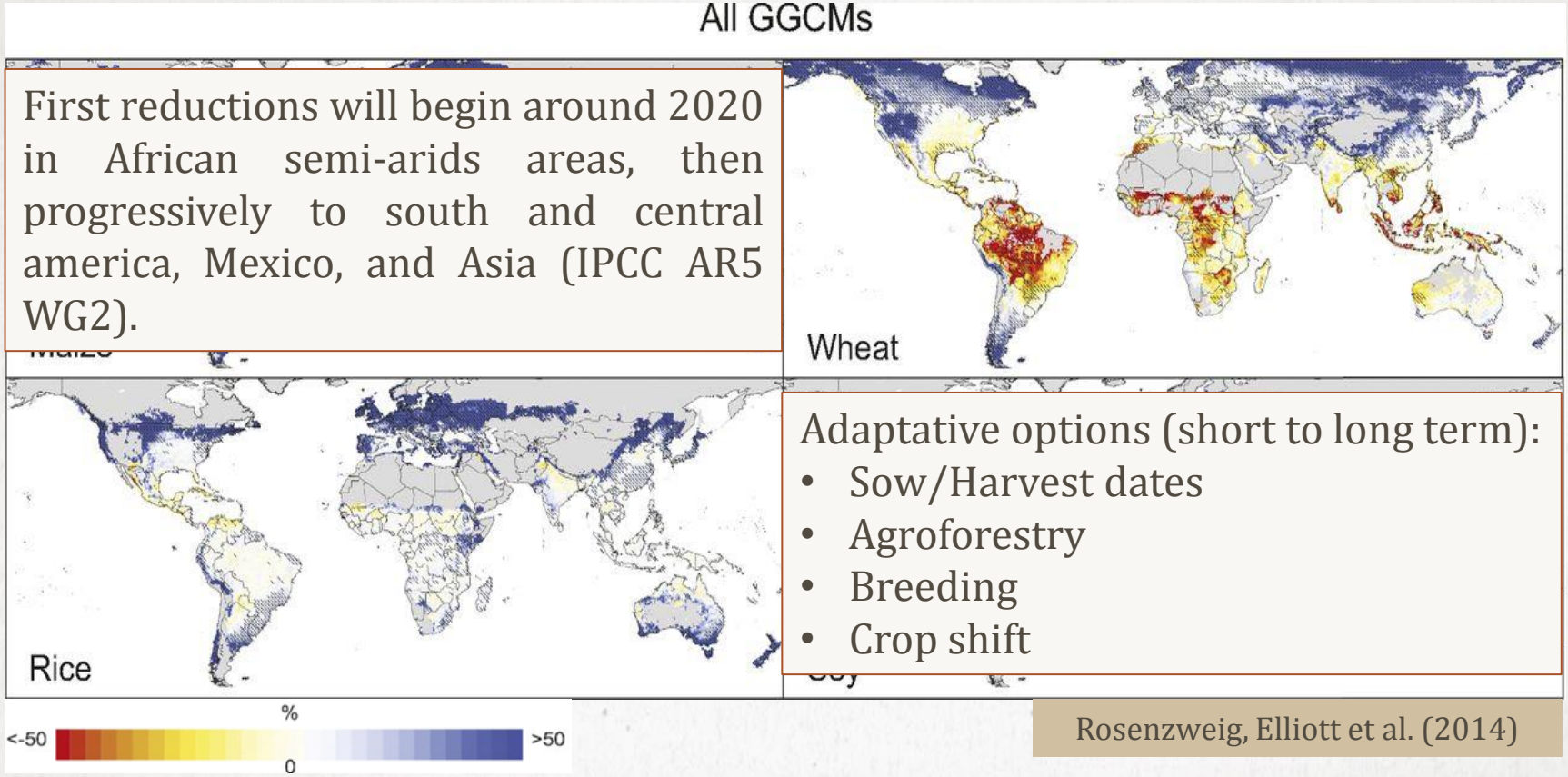
IMPACT OF FUTURE CLIMATE ON CROP YIELD



First reductions will begin around 2020 in African semi-arids areas, then progressively to south and central america, Mexico, and Asia (IPCC AR5 WG2).

Adaptative options (short to long term):

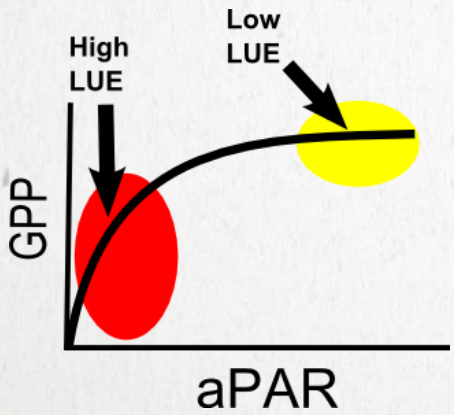
- Sow/Harvest dates
- Agroforestry
- Breeding
- Crop shift

Rosenzweig, Elliott et al. (2014)

A TRADE-OFF BETWEEN SHADE AND YIELD ?

Agroforestry may regulate microclimate and crop temperature.

- What is the expected reduction on temperature?
- Effect of shade tree species, density and management?
- How to cope with local climate, elevation, bearing…
- Does LUE compensate somehow for light reduction under shade ?



Crop yield ?

LUE increase under shade ?

Regulation of crop canopy temperature ?

METHODS

Field experiments extremely useful but hard to maintain or extend:

- Trees take decades to mature
- Huge amount of management/climate options to test

Numeric models

Agroforestry is spatialy heterogeneous

Need 3D plant-to-plot models + Accurate light interception and energy balance + process-based model + (half-) hour time step.
Model selected here: MAESPA (Duursma et al. 2012)

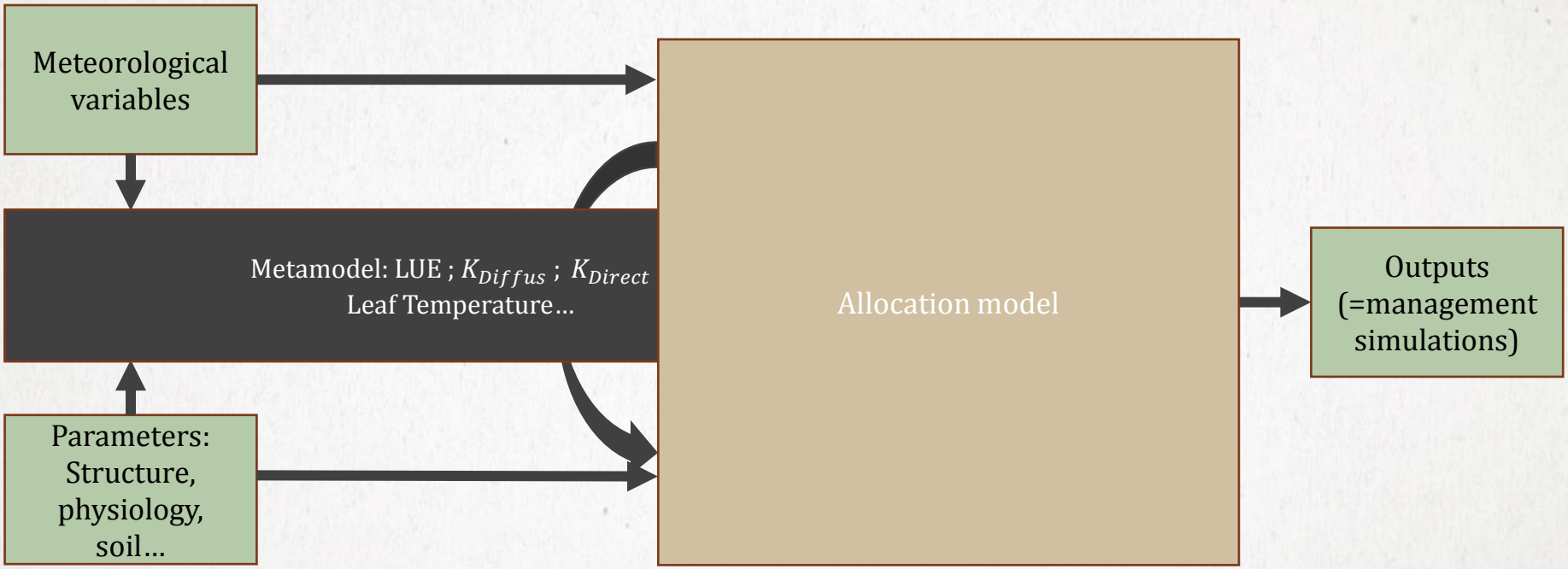
Crop model, horizontally uniform

Allocation, growth and yield over full rotation + Plot scale + Fast + Process-based

Opportunity for model coupling

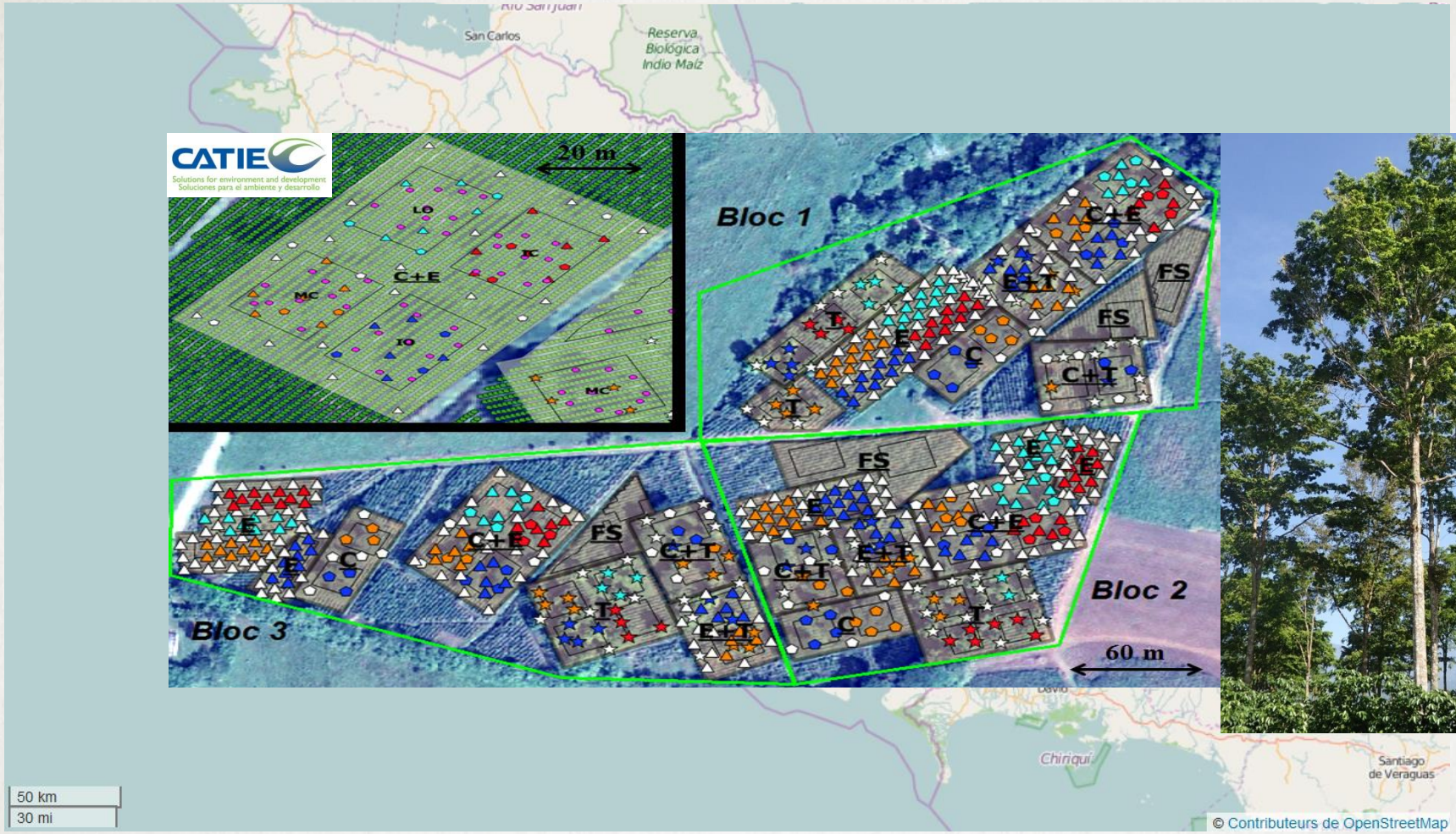
METAMODELS:

Integrate Spatial Effects Computed From MAESPA Into Plot Scale Model Through Summary Equations



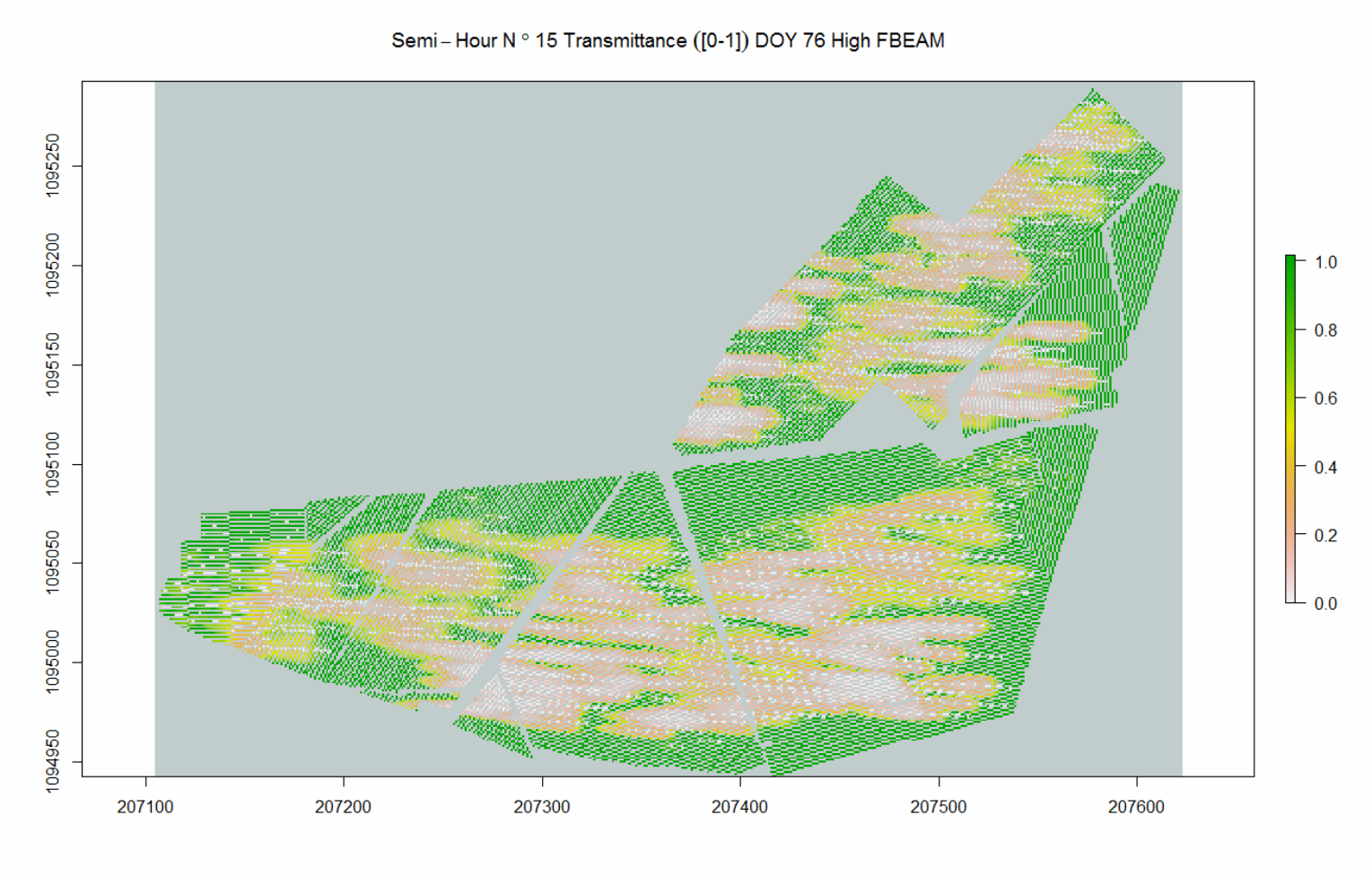
MAESPA VALIDATION

15 years-old agroforestry trial in CATIE research center (Haggar et al., 2011)



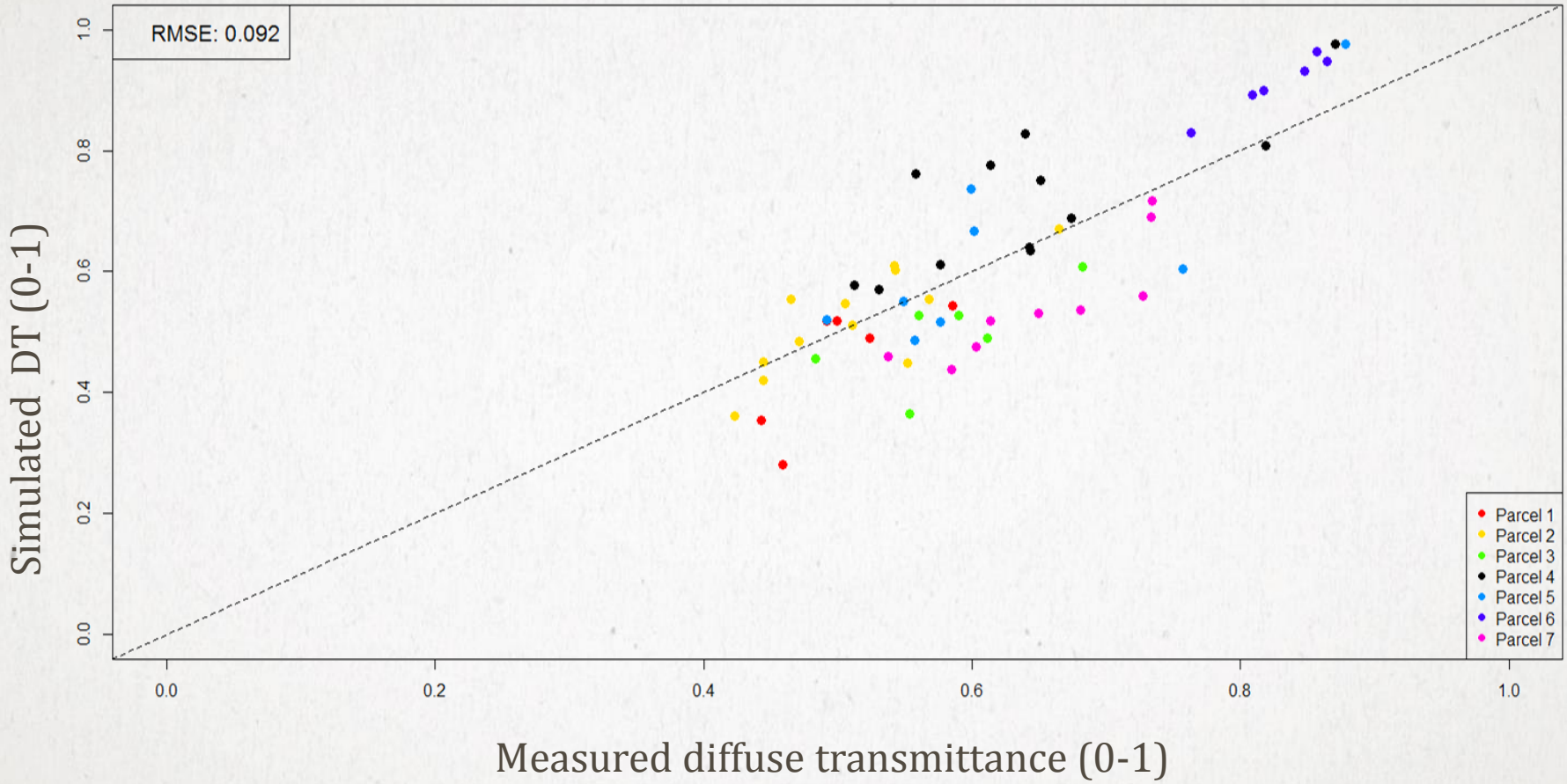
MAESPA LIGHT INTERCEPTION VALIDATION (1)

Simulated Total Transmittance (Day of Year 76, by hour)



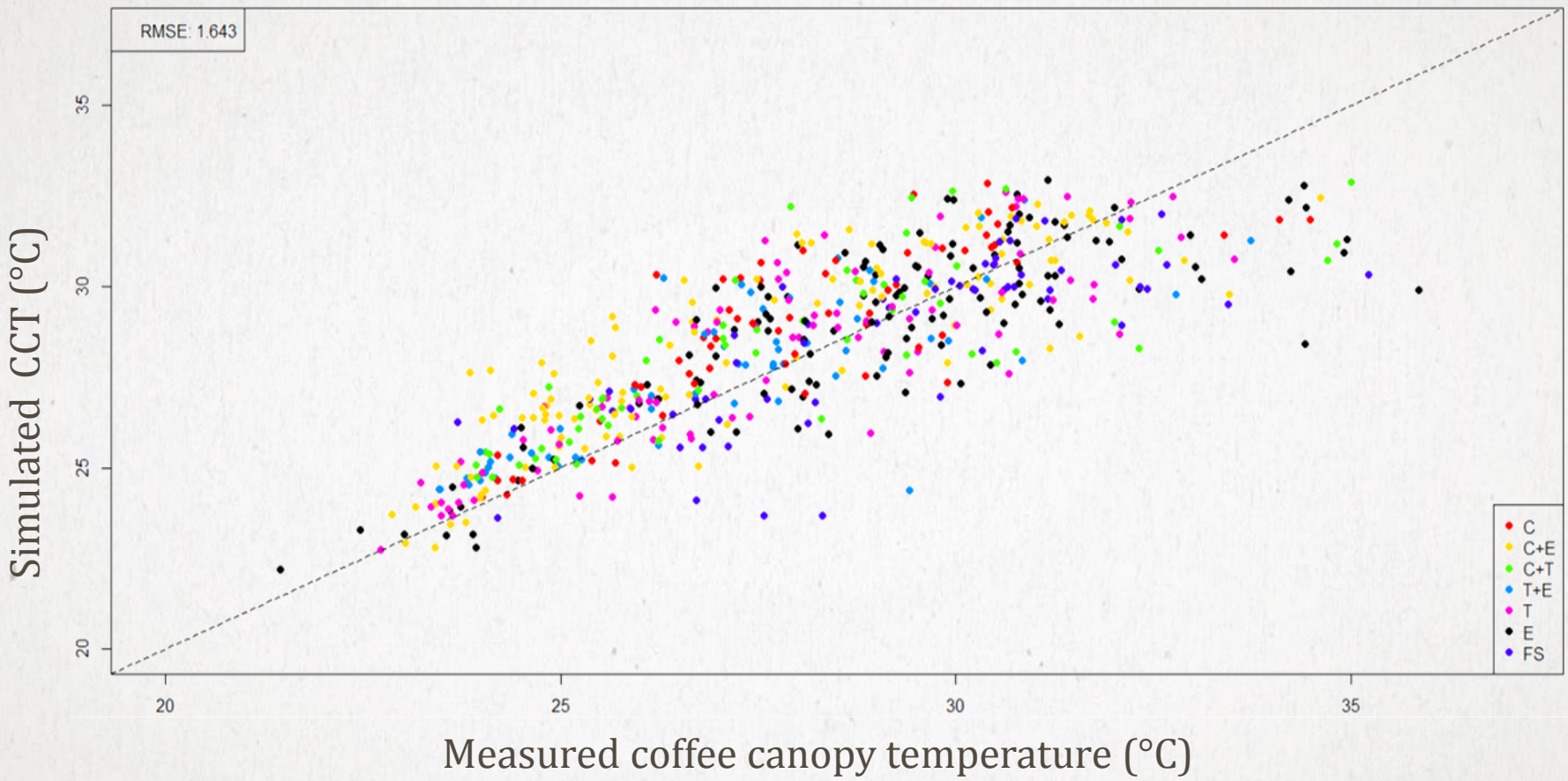
MAESPA LIGHT INTERCEPTION VALIDATION (2)

MAESPA light interception validation through diffuse transmittance from hemispheric photograph



MAESPA CANOPY TEMPERATURE VALIDATION

MAESPA coffee canopy temperature validation through thermocouples measurements



SIMULATION OF COFFEE MANAGEMENT SCENARIOS

Climate

RCP 4.5

RCP 8.5

X

Locati

Aquiar
(~1000m

sit

400

125

X

Grow freely, low densities, make high coverage (High LAI)

2
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.
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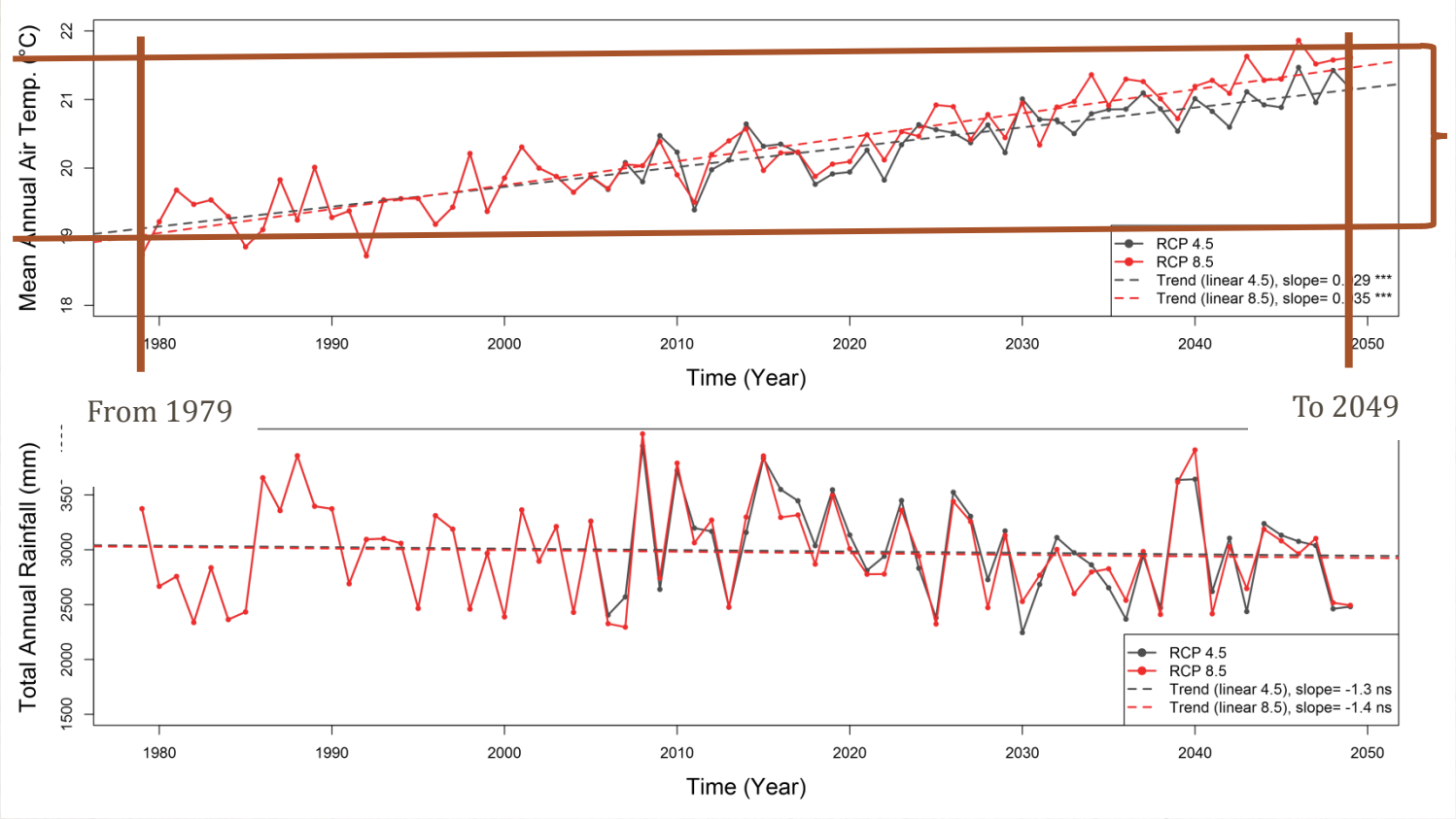
35

FUTURE CLIMATE, SIMULATED TO THE POINT

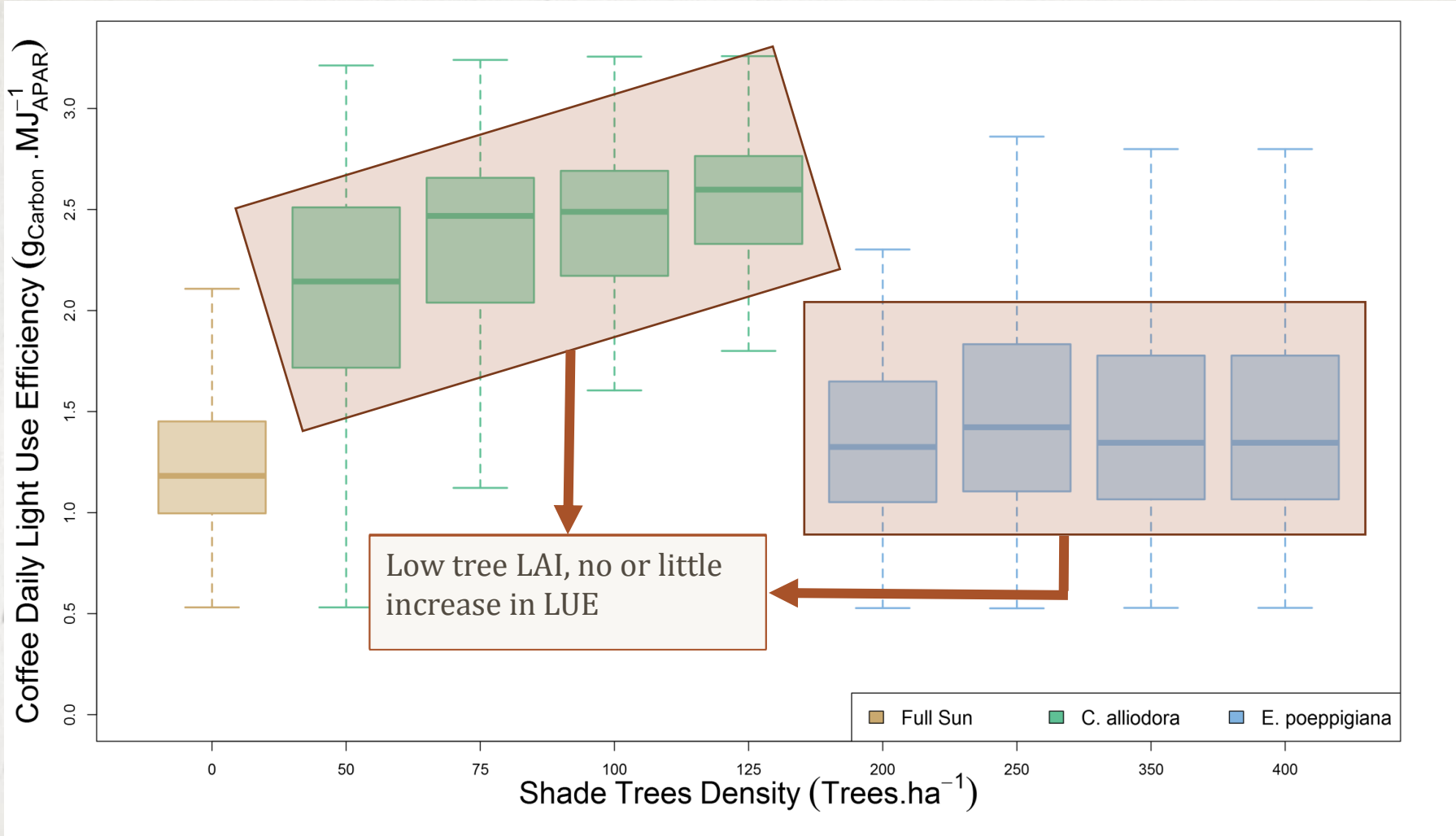


2.48°C increase for RCP8.5

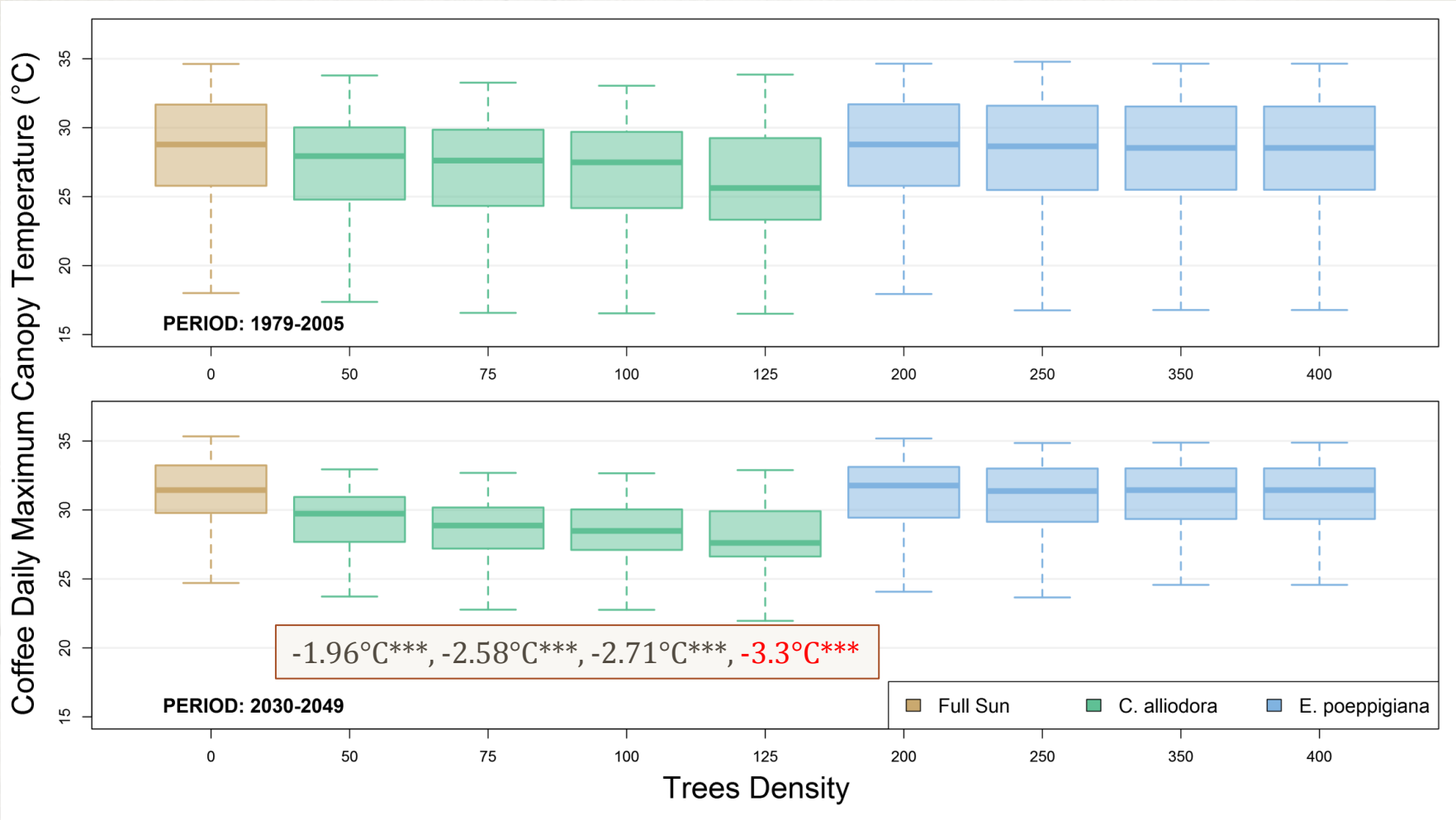
Practically no change expected for precipitations

Statistical downscaling from 14 GCMs to 5 km definition following Hidalgo et al. (2016, in prep)

COFFEE LIGHT USE EFFICIENCY (1979-2050 RCP 8.5, AQUIARES)



COFFEE DAILY MAXIMUM CANOPY TEMPERATURE (RCP 8.5, AQUIARES)

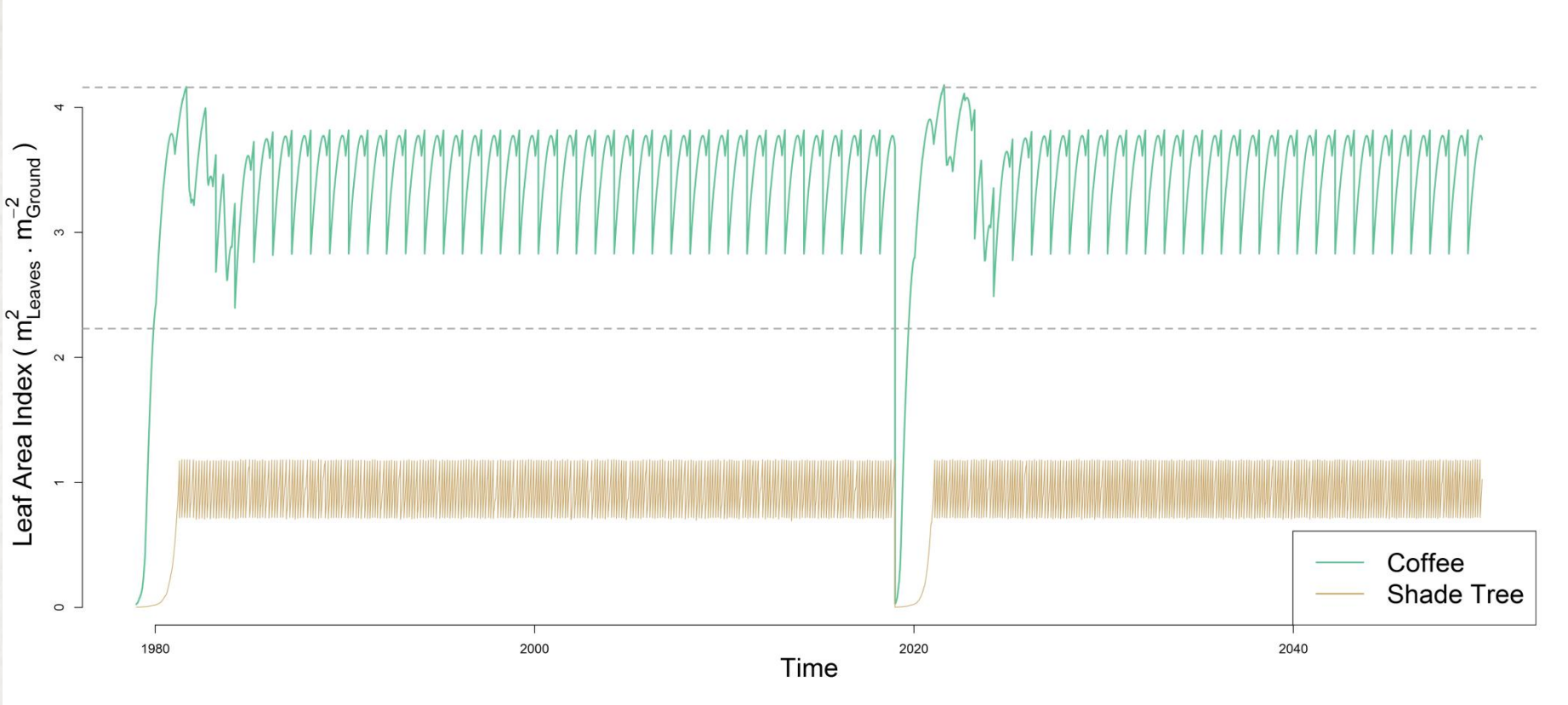


CROP MODEL SIMULATIONS EXAMPLE:

TWO CYCLES (1979 TO 2049)
AQUIARES (LOWLAND)
RCP 8.5
***Cordia alliodora,* 50 tree ha^{-1}, thinned)**

CROP MODEL :

Aquiares (Lowland), RCP 8.5, Shade = *Cordia alliodora* (50 tree ha^{-1}, thinned)



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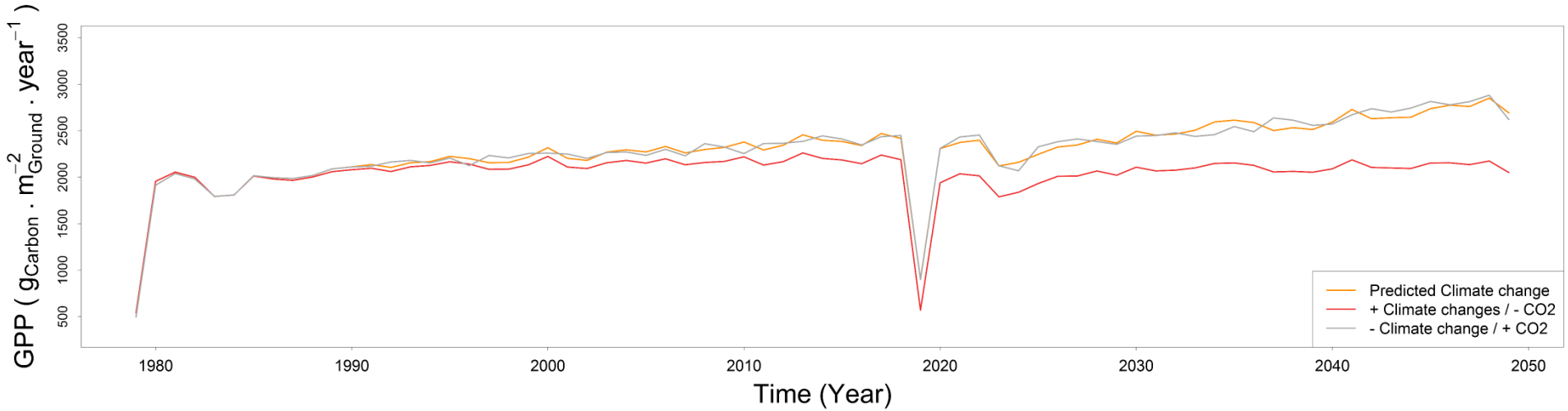

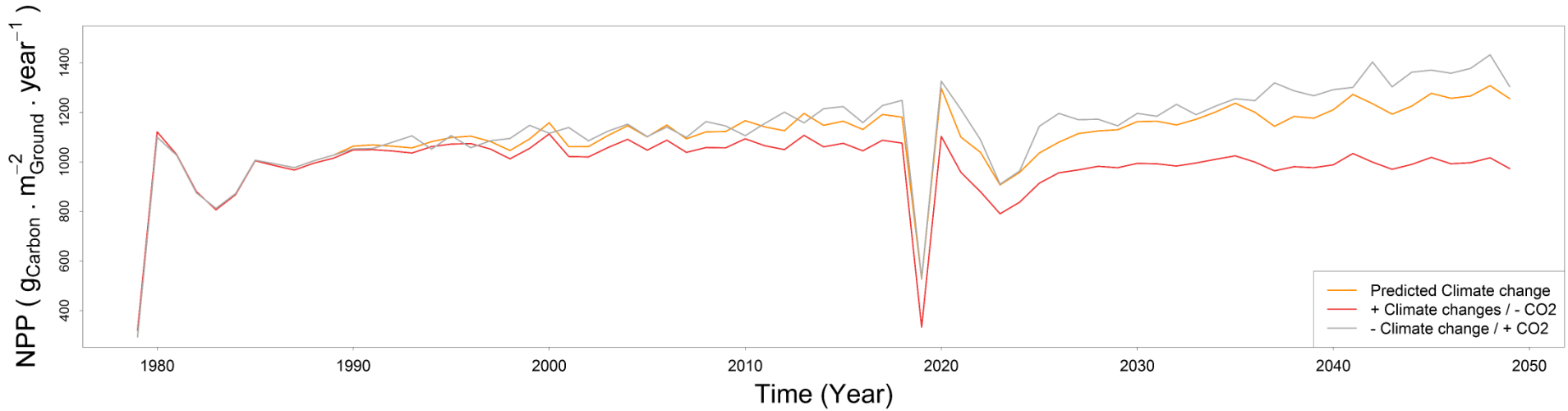

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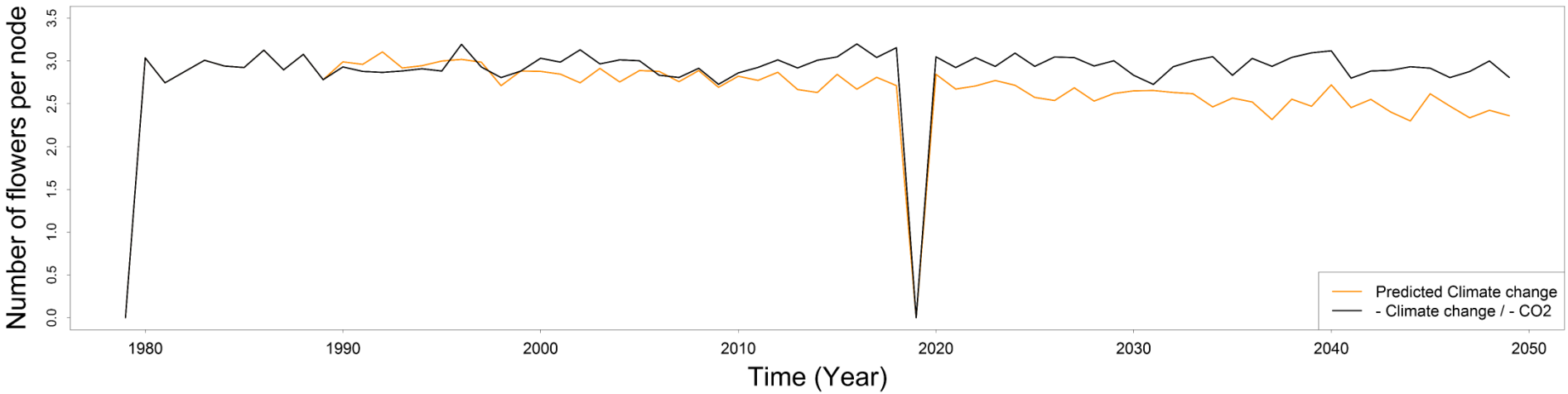

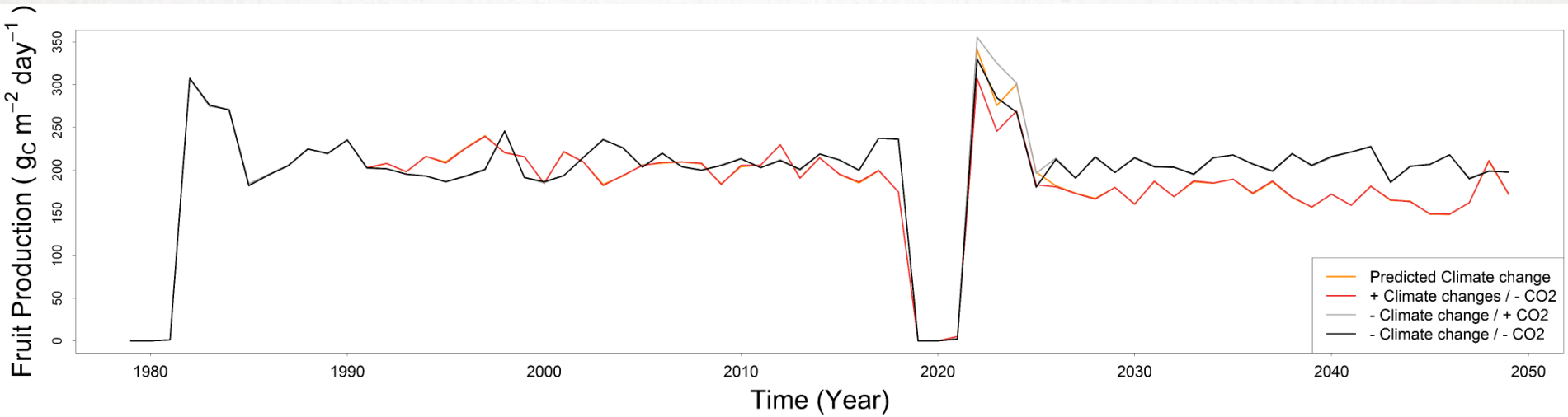

CROP MODEL :

Aquiares (Lowland), RCP 8.5, Shade = *Cordia alliodora* (50 tree ha^{-1}, thinned)

Key variables evolution compared to reference (no climate change and no CO2 increase) for last ten years (2040-2050)

	Temperature	CO2	GPP	Maintenance respiration	Growth respiration	NPP	Budbreak	Flowers per node	LAI	Annual Fruit production
Predicted climate change	+ 1.95°C***	+48%***	+25%***	+43%***	+15%	+17%	-19%***	-15%***	=	-19%***
+CC - CO2	+ 1.95°C***	=	-1.3%^{ns}	+9.4%***	-7.8%	-7.0%	-19%***	-15%***	=	-19%***
-CC + CO2	=	+48%***	+27 %***	+29.5%***	+25%	+26%	=	=	=	=

Mean difference is not significant but trend do

CONCLUSION

- Coupling a 3D with a crop allocation model allows to simulate photosynthesis, light use efficiency and yield over full rotations while taking spatial heterogeneity into account
- Coffee yield could be impacted by 12% reduction under future climate due to T°C without full compensation by CO2 : adjusting shade will be crucial then !
- Models should allow to optimize shade and yield under various geographic location, management and climate scenarios
- Simulations will be extended to 2100 (no strong differences between RCPs until 2049)
- Further analyses will be conducted over all the scenarios

ACKNOWLEDGMENTS

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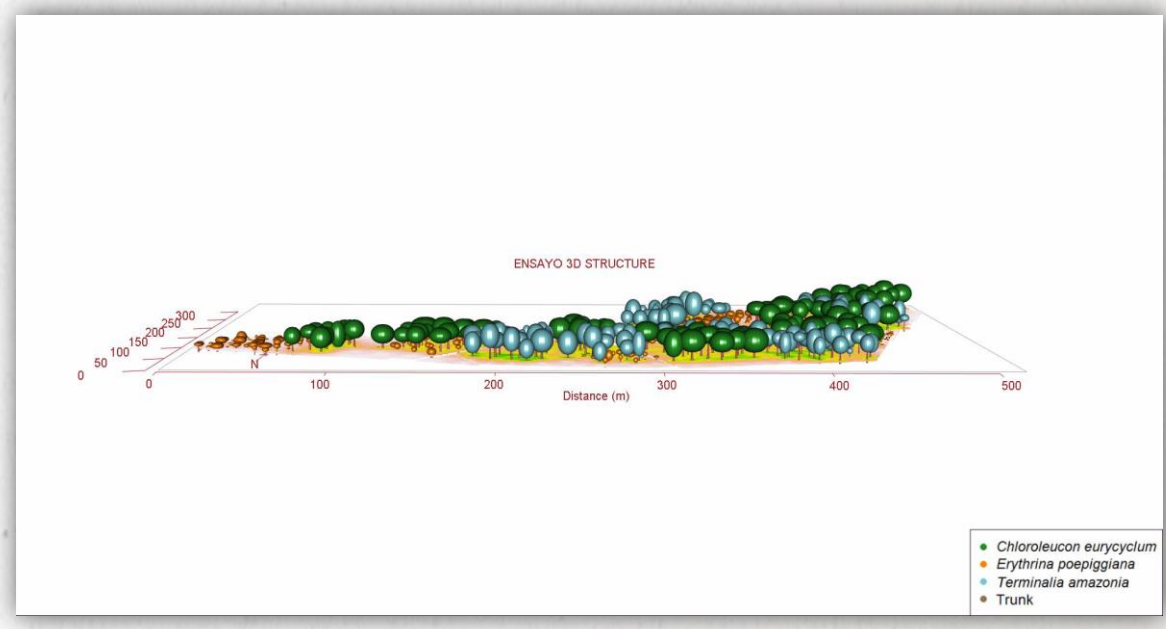
- UCR (University of Costa Rica)
- SAFSE Project: http://safse.cirad.fr/le-projet



ANNEXES

DOWNSCALING TECHNIQUE

- Statistical downscaling:
  - Depends on current empirical relationships
  - Low computational demand
  - Long and high quality data series
  - Hard to apply in complex environments