A Multivariate, Multi Time-scale Calibration Framework for Managed Croplands
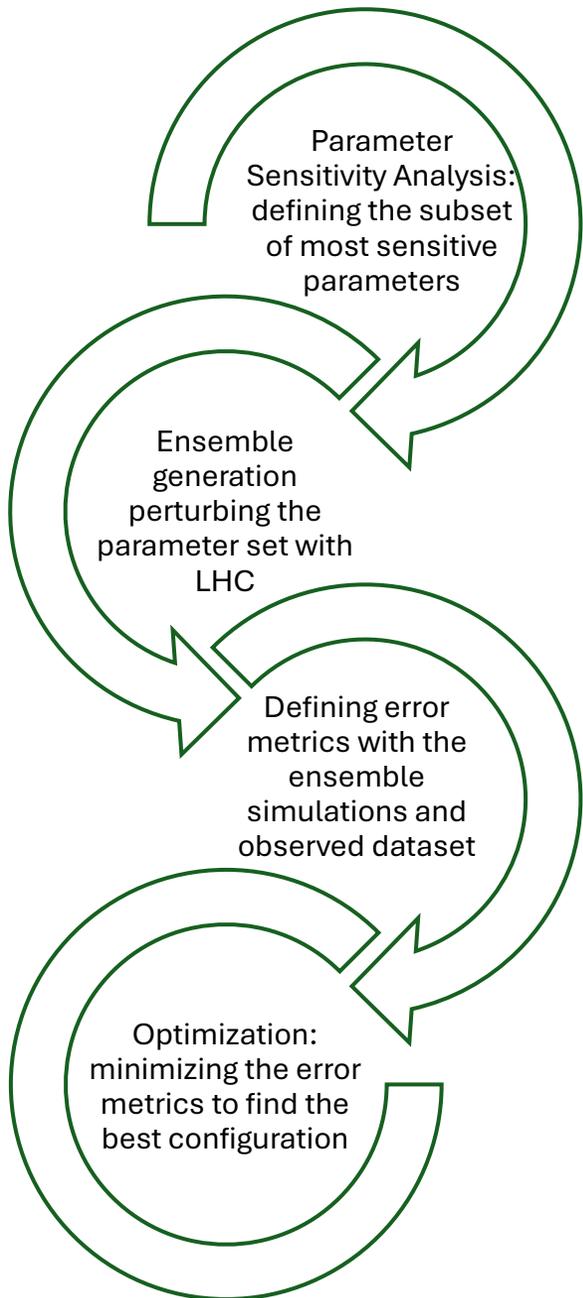
Ruparati Chakraborti[1]
Cesar Jimenez Rodriguez[1]
Mauro Sulis[1]

1 Remote Sensing and Natural Resources Modelling Group, LIST
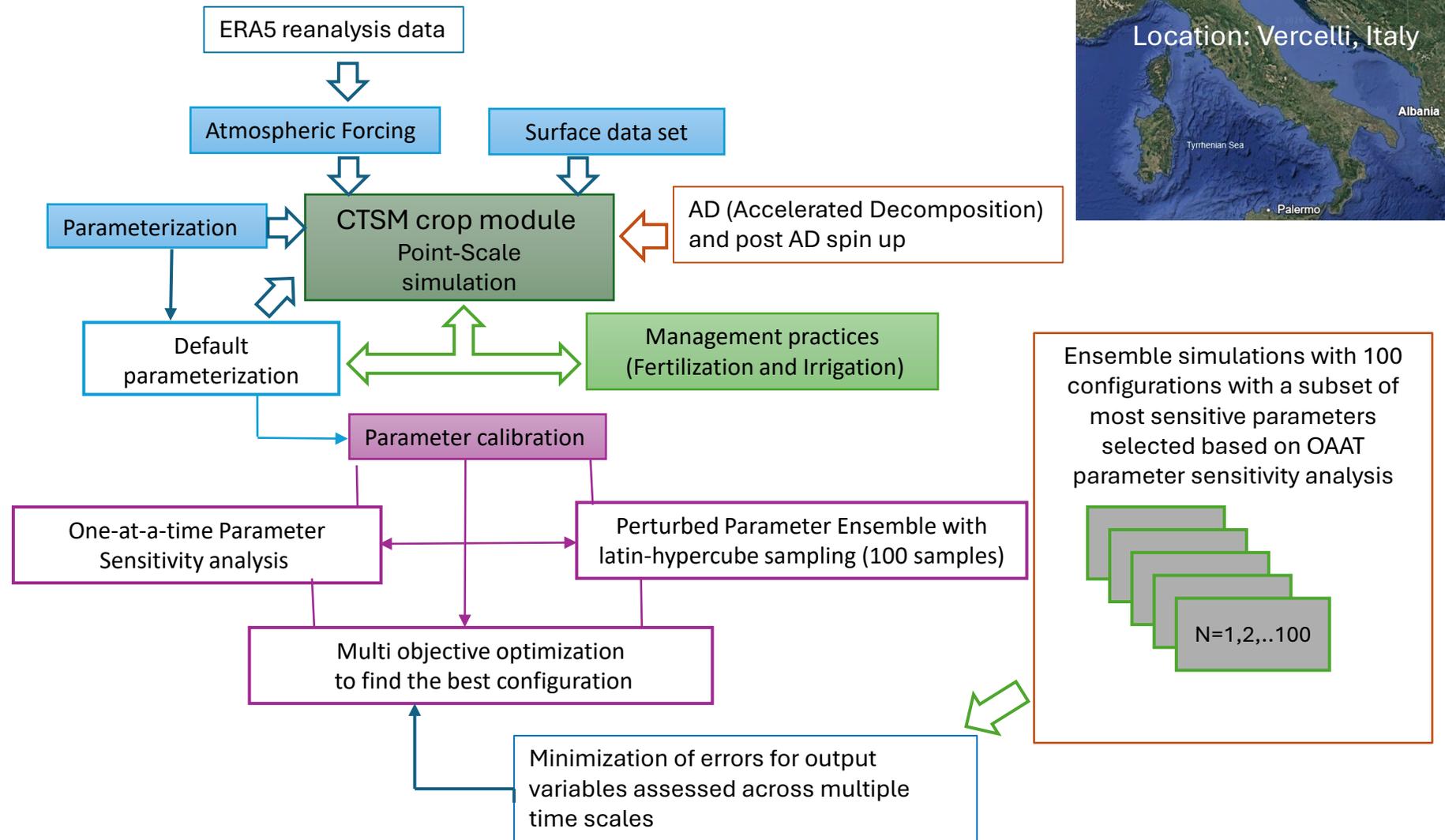
Outline

- Methodological framework explaining the key steps of setting up the model activating the crop module for point scale simulation and calibration methods

- Simulated variable sensitivity across varied management practices

- One-at-a-time Parameter Sensitivity Analysis

- PPE experiments : the best configuration varies across variables and across time scale

- Multi –objective optimization framework to identify one optimal solutions

- Validation of the calibrated model results

- Summary

- Future Plans

Methodological Framework

Calibration

- Parameter Sensitivity Analysis: defining the subset of most sensitive parameters
- Ensemble generation perturbing the parameter set with LHC
- Defining error metrics with the ensemble simulations and observed dataset
- Optimization: minimizing the error metrics to find the best configuration

Location: Vercelli, Italy

ERA5 reanalysis data

Atmospheric Forcing

Surface data set

Parameterization

CTSM crop module
Point-Scale simulation

AD (Accelerated Decomposition) and post AD spin up

Default parameterization

Management practices
(Fertilization and Irrigation)

Parameter calibration

One-at-a-time Parameter Sensitivity analysis

Perturbed Parameter Ensemble with latin-hypercube sampling (100 samples)

Ensemble simulations with 100 configurations with a subset of most sensitive parameters selected based on OAAT parameter sensitivity analysis

N=1,2,..100

Multi objective optimization to find the best configuration

Minimization of errors for output variables assessed across multiple time scales

*Dagon, K., B.M. Sanderson, R.A. Fisher, D.M. Lawrence (2020), A machine learning approach to emulation and biophysical parameter estimation with the Community Land Model, version 5. Advances in Statistical Climatology, Meteorology and Oceanography, 6, 223-244

Sensitivity of yield across varied management practices (irrigation and fertilization) and comparison with the observed yield

Time Series of Rainfed, Irrigated, and Observed Yields (2006–2023)
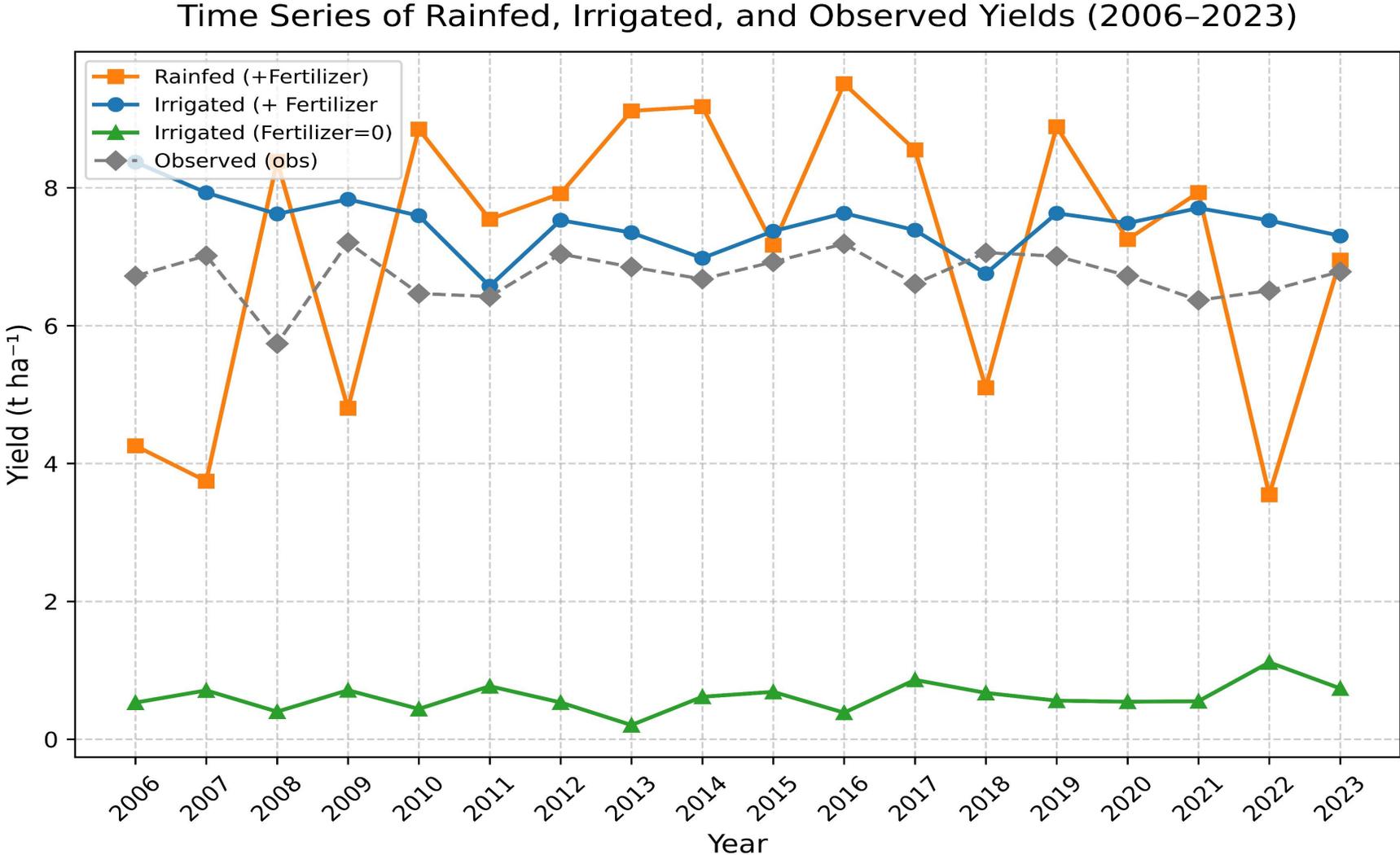
Observed yield data source: Istat (Italian National Institute of Statistics)

Parameter Sensitivity Analysis

Parameter sensitivity responds differently across management scenarios ?

Plant Hydraulics
- psi50
- krmax

Radiation
- rholvis
- taulvis
- rhosvis

Allocation
- leafcn
- flivewd
- livewdcn
- arooti

Phenology
- mxmat
- Laimx
- grnfill
- baset

Photosynthesis
- medlynslope
- slatop

Parameter ranking based on sensitivity metric

Irrigated

Rank	GPP	TLAI	GRAINC_TO_FOOD	QVEGT
1	mxmat	mxmat	fleafi	mxmat
2	s_vcad	laimx	s_vcad	s_vcad
3	leafcn	fleafi	mxmat	medlynslope
4	slatop	s_vcad	laimx	leafcn
5	fleafi	leafcn	leafcn	rholnir
6	medlynslope	slatop	baset	taulnir
7	laimx	leaf_long	slatop	fleafi
8	grnfill	lfemerg	grnfill	laimx
9	flivewd	lmr_intercept_atkin	lmr_intercept_atkin	lmr_intercept_atkin
10	livewdcn	grperc	hybgdd	rhosnir
11	i_vcad	arooti	arooti	slatop
12	baset	grnfill	flivewd	lfemerg
13	arooti	hybgdd	livewdcn	tausnir
14	lfemerg	i_vcad	medlynslope	grnfill
15	rholvis	rholnir	grperc	arooti
16	lmr_intercept_atkin	taulnir	fun_cn_flex_b	i_vcad
17	taulvis	medlynslope	i_vcad	grperc
18	grperc	baset	graincn	flivewd
19	rhosvis	rhosnir	manunitro	livewdcn
20	manunitro	kc_nonmyc	lfemerg	dleaf

Rainfed

Rank	GPP	TLAI	GRAINC_TO_FOOD	QVEGT
1	mxmat	mxmat	fleafi	mxmat
2	leafcn	laimx	mxmat	s_vcad
3	s_vcad	fleafi	s_vcad	medlynslope
4	fleafi	s_vcad	laimx	leafcn
5	laimx	leafcn	leafcn	rholnir
6	grpnow	leaf_long	baset	fleafi
7	baset	lfemerg	lmr_intercept_atkin	grpnow
8	rholnir	grpnow	grnfill	lmr_intercept_atkin
9	i_vcad	lmr_intercept_atkin	graincn	rhosnir
10	lfemerg	grperc	hybgdd	baset
11	psi50	baset	arooti	laimx
12	rholvis	arooti	flivewd	lfemerg
13	hybgdd	grnfill	grperc	psi50
14	rhosvis	medlynslope	livewdcn	hybgdd
15	froot_leaf	hybgdd	rholnir	i_vcad
16	krmax	i_vcad	lfemerg	froot_leaf
17	grperc	rholnir	i_vcad	krmax
18	rhosnir	flivewd	allconss	grperc
19	flivewd	livewdcn	grpnow	dleaf
20	arooti	rhosnir	manunitro	arooti

Perturbed Parameter Ensemble

Diurnal Variability of GPP: monthly variation of the best configuration

Legend:
- FLUXNET
- CLM (default)
- Best matched ensemble member
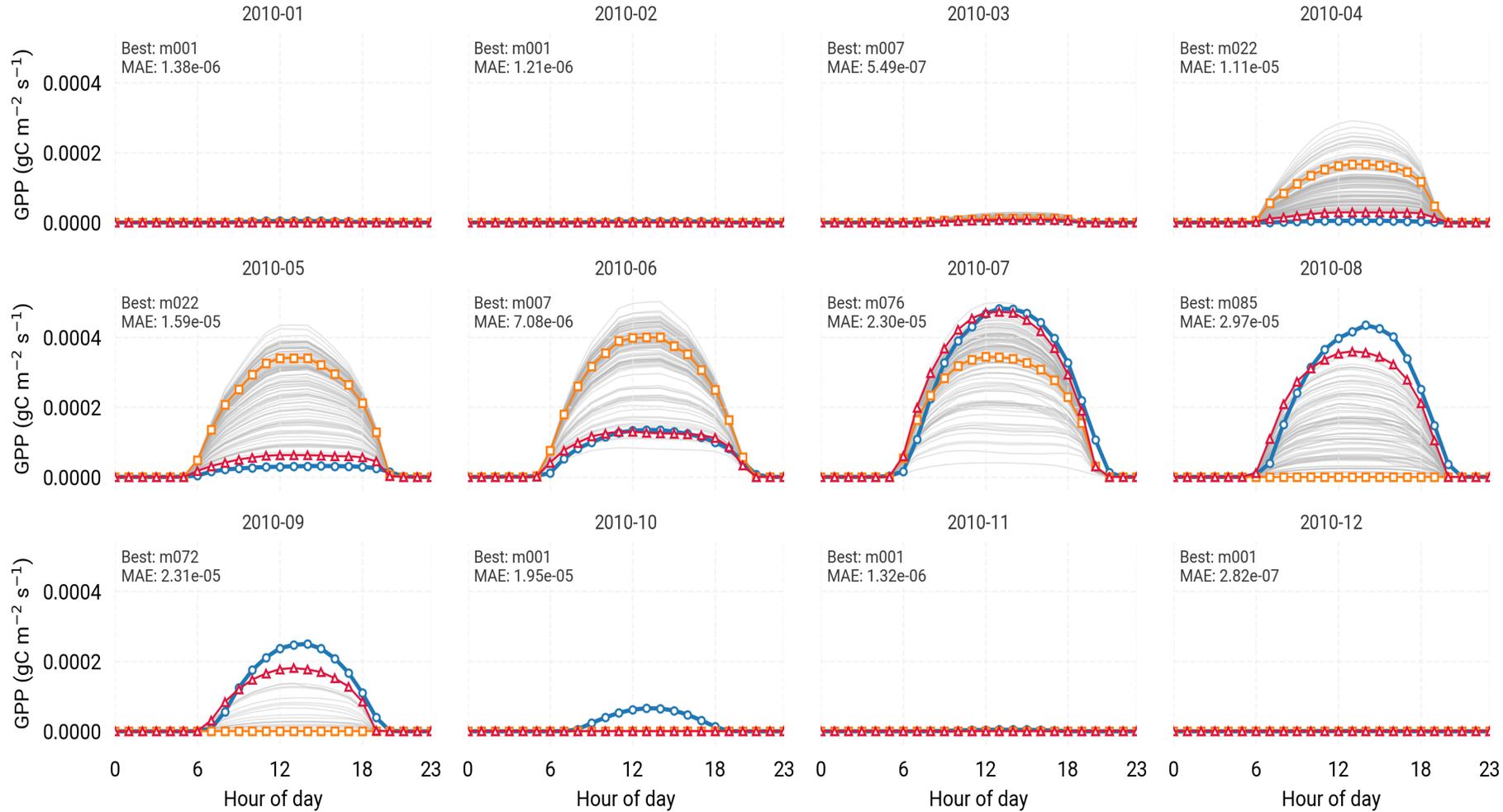
2010-01 — Best: m001, MAE: 1.38e-06

2010-02 — Best: m001, MAE: 1.21e-06

2010-03 — Best: m007, MAE: 5.49e-07

2010-04 — Best: m022, MAE: 1.11e-05

2010-05 — Best: m022, MAE: 1.59e-05

2010-06 — Best: m007, MAE: 7.08e-06

2010-07 — Best: m076, MAE: 2.30e-05

2010-08 — Best: m085, MAE: 2.97e-05

2010-09 — Best: m072, MAE: 2.31e-05

2010-10 — Best: m001, MAE: 1.95e-05

2010-11 — Best: m001, MAE: 1.32e-06

2010-12 — Best: m001, MAE: 2.82e-07

Axis labels: GPP (gC m^{-2} s^{-1}); Hour of day (0, 6, 12, 18, 23)

Identification of the best configuration from 100 ensemble members!!

Observed GPP : FLUXNET eddy covariance tower site IT-Cas

Perturbed Parameter Ensemble

Annual variability of yield
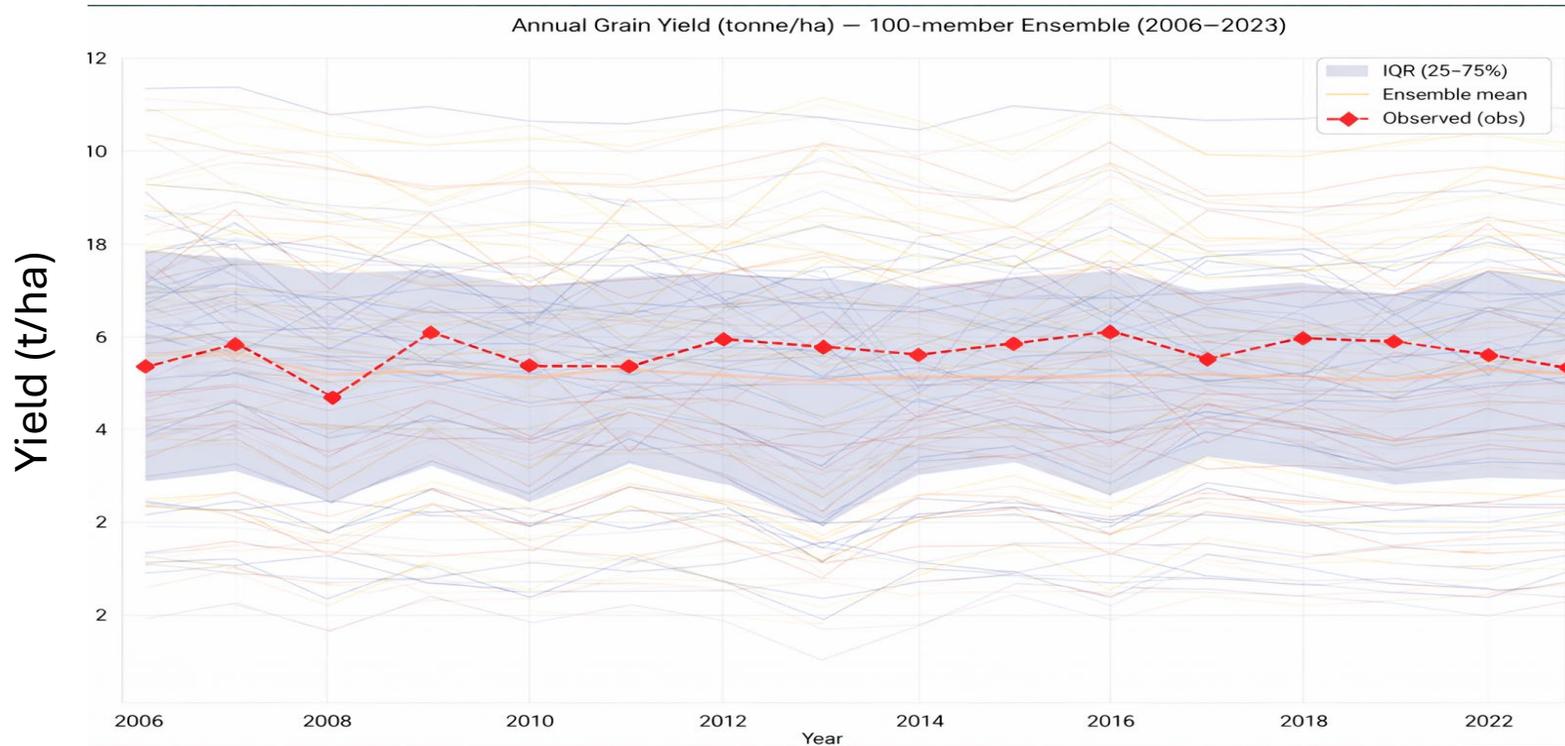
Inter annual variability of the best configuration

Identification of the best configuration from 100 ensemble members!!
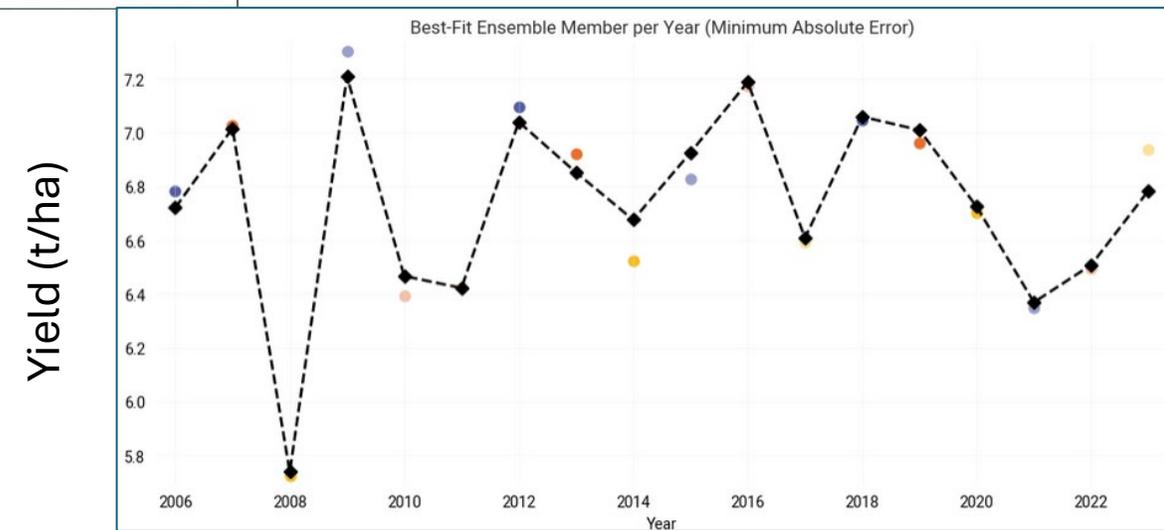
Validation

Observed vs Simulated Yield (default config)
MAE = 1.537
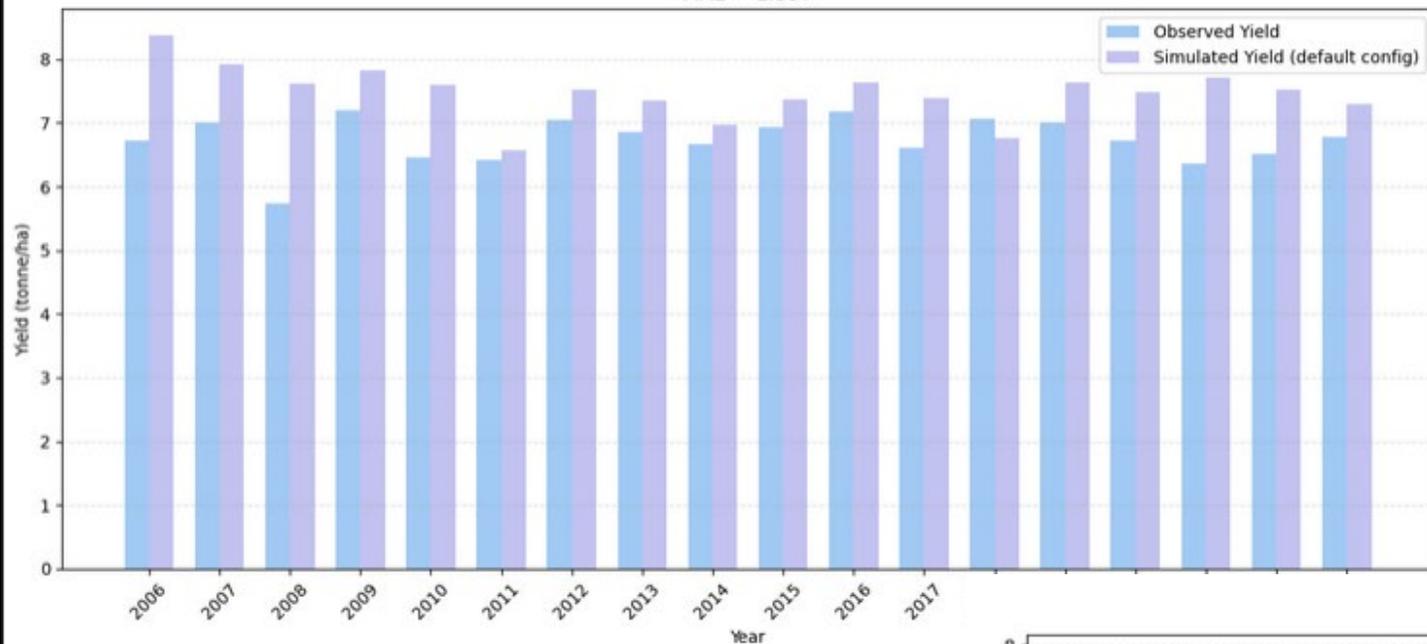
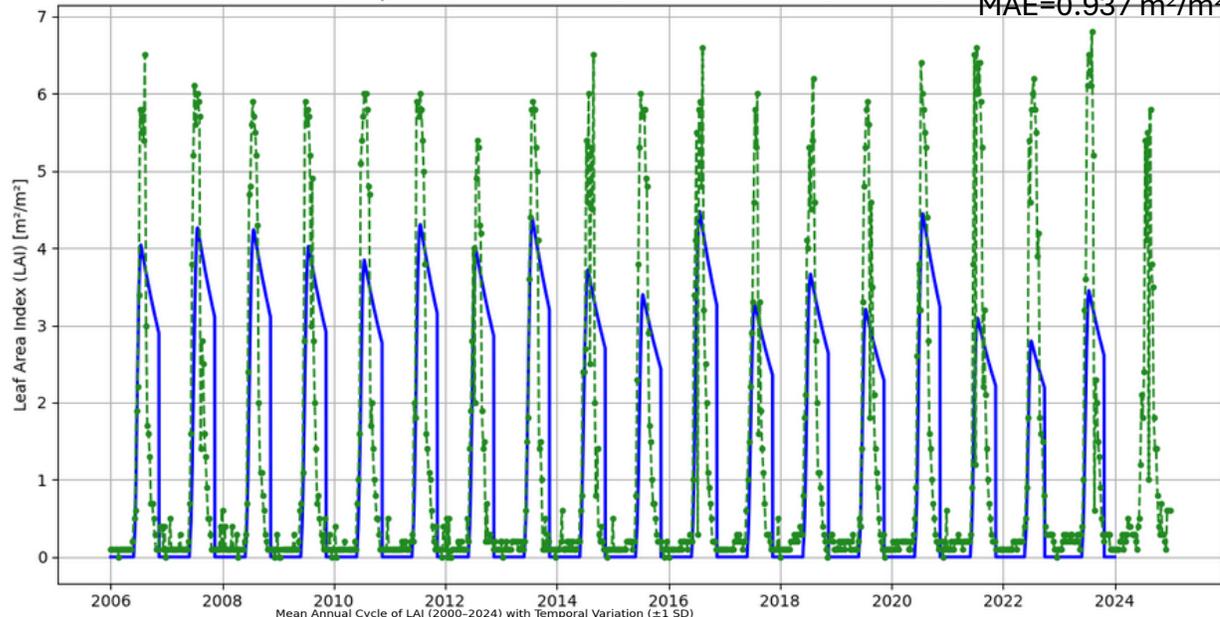Annual Yield estimation with the calibrated and default configured model

For yield, we observed **the reduction of 64 % in the 'Mean Absolute Error'** (aggregated across all the years, 2006 to 2024), when we compare the simulations with the calibrated set of parameters against the simulations with the default configuration

Observed vs Simulated Yield (calibrated)
MAE = 0.551
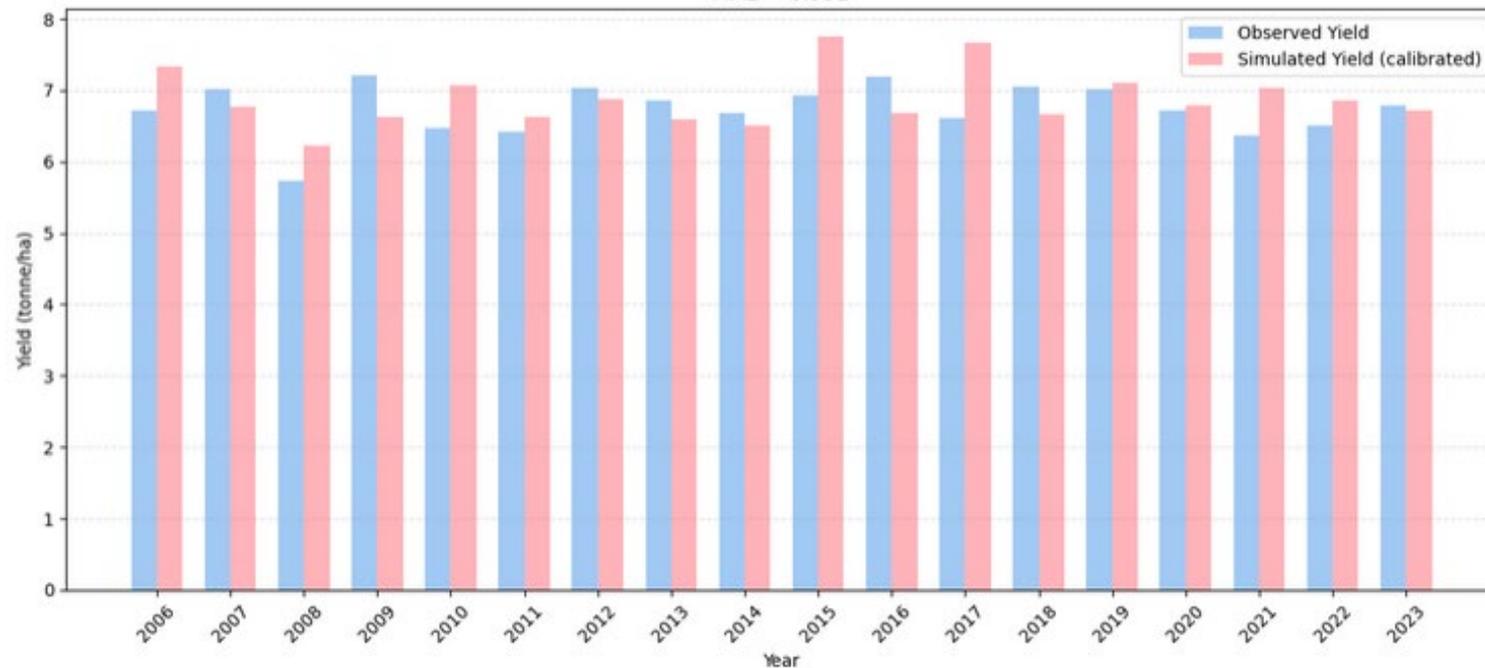
Validation

Comparison of CLM Total LAI (TLAI) and MODIS LAI (2006–2024)

Default configuration
MAE=0.937 m²/m²

Leaf Area Index

Comparison in the calibrated model simulation with the default configured simulation when both are validated against the observed dataset

For LAI, we observe **reduction of 40 % in the 'Mean Absolute Error'** (aggregated across all the years, 2006 to 2024), when we compare the simulations with the calibrated set of parameters against the simulations with the default configuration

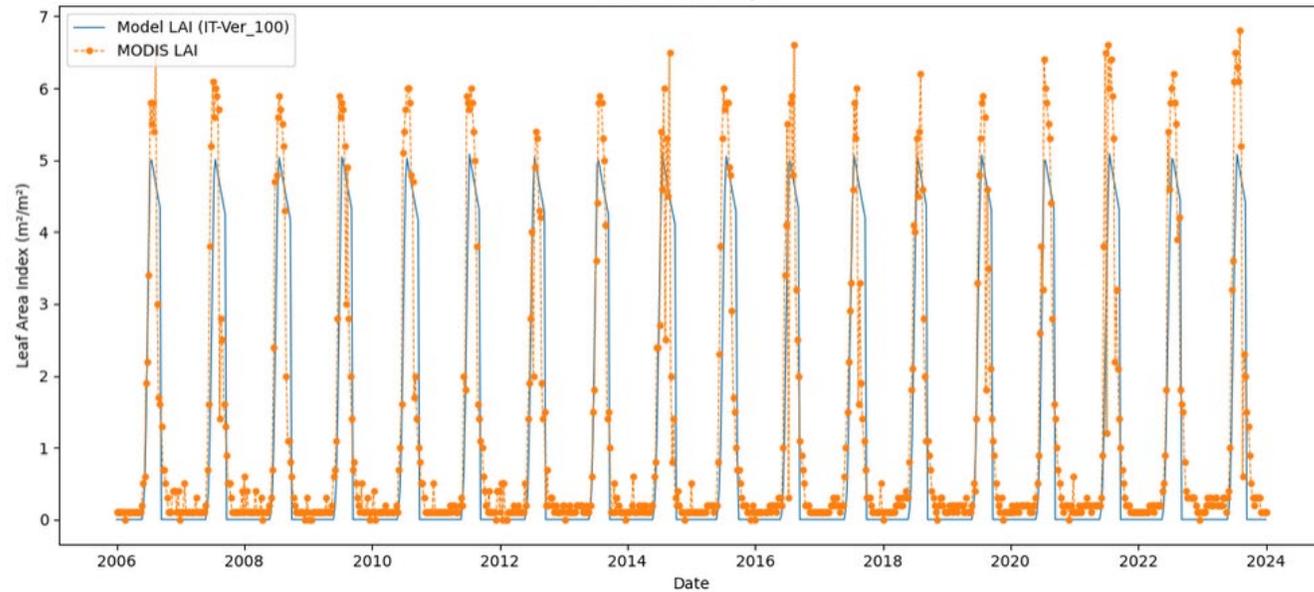**Comparison of mean annual cycles between calibrated and default config**

Mean Annual Cycle of LAI (2000–2024) with Temporal Variation (±1 SD)
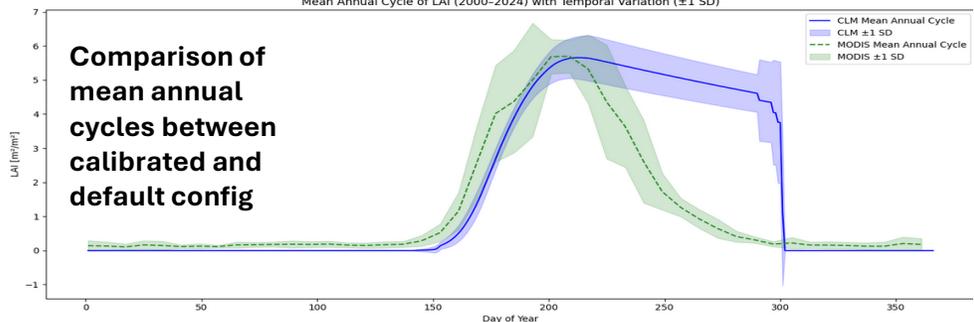
Mean Annual Cycle of LAI (2000–2024) with Temporal Variation (±1 SD)
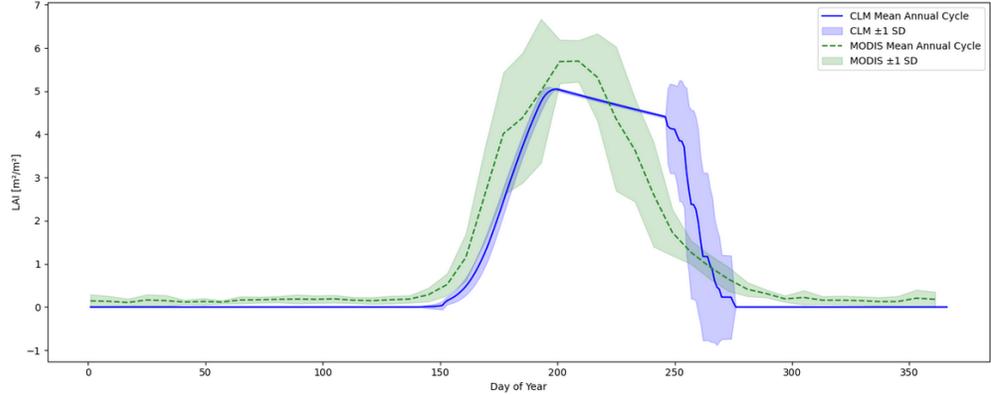
Calibrated

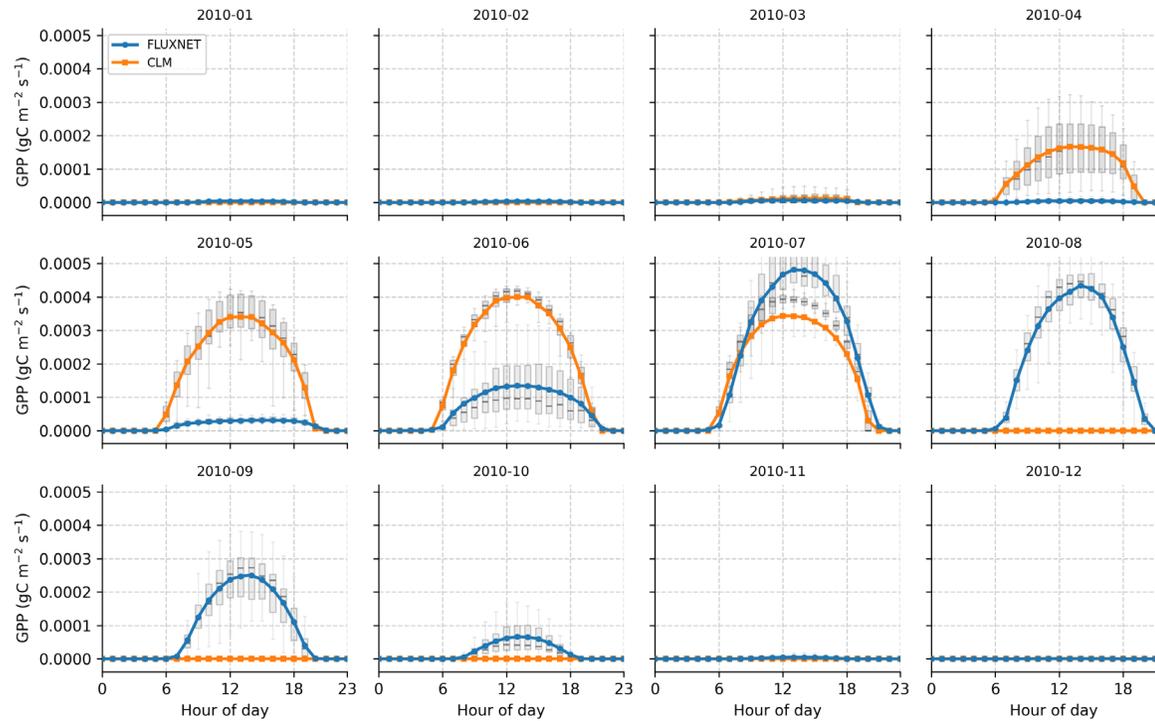MODIS vs Model LAI (IT-Ver_100)
MAE = 0.564 m²/m²
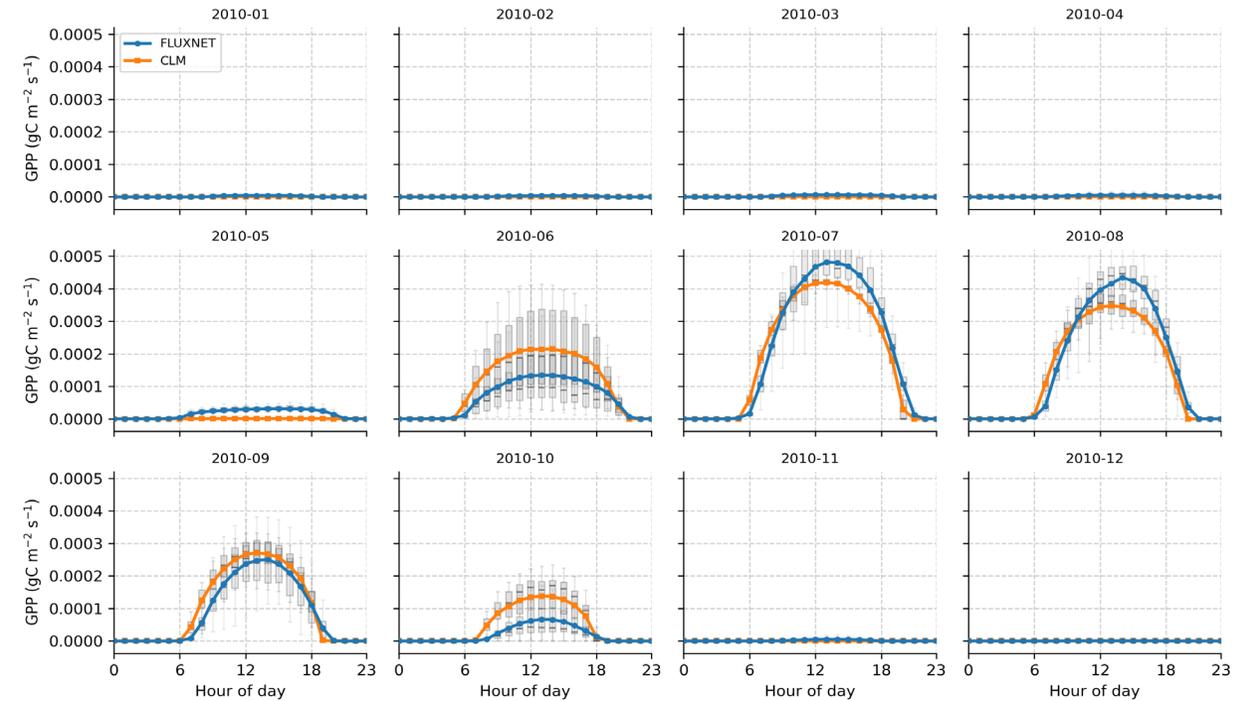
Validation

Gross Primary Productivity

Default

MAE=5.41*10^{-5} gC/m^2/s

Calibrated

MAE=1.44*10^{-5} gC/m^2/s

For GPP, we observed **the reduction of 73 % in the 'Mean Absolute Error'** when we compare the simulations with the calibrated set of parameters against the simulations with the default configuration

Summary and Future Plans

We observed that sensitivity of the parameters varies across different management practices and across variables when perturbed one at a time

Best configuration of the parameter sets varies across different output variable and it also varies when the variables are being integrated with different time scale

To identify the optimal solution we adopted multi-variate, multi time –scale optimization framework

In the next step we plan to address the following question:

- Does the optimal configuration of the parameter set varies across different climate region and land surface characteristics?

- How we can develop a robust calibration framework to identify a global optimal solution ?

Global Distribution of Rice Flux-Tower Sites

We plan to extend the framework across a global network of FLUXNET rice tower sites to identify a robust optimal parameter configuration.