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An international intercomparison and benchmarking of crop and pasture models simulating GHG emissions and C sequestration

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Session L3.1 Climate adaptation and mitigation services

International & collaborative work

under the umbrella of the Soil C&N cycling cross-cutting group of the Global Research Alliance

INRA SCIENCE & IMPACT — GLOBAL RESEARCH ALLIANCE ON AGRICULTURAL GREENHOUSE GASES — AgMIP — FACCEJPI Agriculture, Food Security and Climate Change

- **4 FACCE JPI projects** : CN-MIP, Models4Pastures, Comet-Global, MAGGNET
- **15 contributing countries**
- **>40 people involved**: modelers, site data providers, coordinators, statisticians, project holders

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The challenge of benchmarking & intercomparison

Why benchmark and inter-compare models?

- Evaluate model performance against others and against data
- Examine where a model fails and why other models do better – improve the model ; where all models fail – drive new science
- Test robustness of models on various geographic & pedoclimatic areas

How to proceed ?

- Test model simulation against independent experimental site data
  - First, without site specific calibration
  - Then, with improved calibration

And then ?

- Improve model performance on future predictions
- Establish guide users on which model to use for which purpose
- Set standards for new models to meet

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Main criteria for site selection

→ Experimental site (grassland or crop including *wheat*)

→ General site description, climate, soil, vegetation/ species/ cultivar, management & site history

→ Published paper

→ Daily climate data covering at least 3 complete years

→ Frequent GHG measurements (ideally with flux towers), soil C stock change and yield

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10 sites selected for model inter-comparison

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28 models from 11 countries

from process-oriented models to simpler models

Arable crops
- Daycent v4.5 (IT), DailyDaycent (CA)
- CERES-EGC (FR)
- STICS v.8.2 (FR)
- APSIM v.7.5 (AU), APSIM v.7.6 (NZ)
- Agro-C v.1.0 (China)
- Infocrop (India)
- EPIC 810 (IT)
- DSSAT v.4.5 (IT), DSSAT45-NGAS (AU)
- DNDC95 (CA)
- FASSET v2.5 (Spain)

Both
- DailyDaycent v.2010 (IT), Daycent (USA)
- RothC10 (IT)
- SALUS (USA)
- DairyModel/ Ecomod v.5.3.1 (AU)

Grasslands
- PaSim (FR)
- APSIM-SoilWater (NZ), APSIM-SWIM v.7.6 (NZ)
- APSIM -GRAZPLAN (CA)
- SPACSYS (UK)
- CenW (NZ)

Ecosystem models
- Landscape DNDC (UK)
- LPJ-Guess 2008 (GE)
- LPJmL v.3.5.3 (GE)

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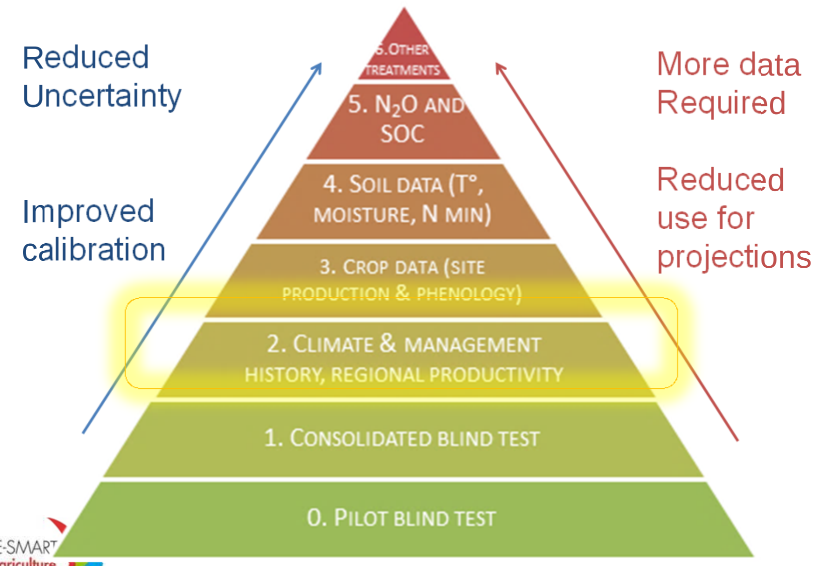
Protocol : inter-compared variables

Production	Arable crop production: Grain yield Grassland production: intake or yield	(kg DM m^{-2} $crop^{-1}$) (kg DM m^{-2} d^{-1})
Vegetation	Leaf Area Index Above-ground Net Primary Production Below-ground Net Primary Production	($m^2.m^{-2}$) (kg DM m^{-2} d^{-1}) (kg DM m^{-2} d^{-1})
Carbon	Gross Primary Production Net Primary Production Ecosystem Respiration Change in total soil organic carbon stock	(kg C m^{-2} d^{-1}) (kg C m^{-2} d^{-1}) (kg C m^{-2} d^{-1}) (kg C m^{-2} yr^{-1})
Nitrogen	N_2O emissions Change in total soil organic nitrogen	(µg N-N_2O m^{-2} d^{-1}) (g N m^{-2} yr^{-1})
Specific for pastures	Enteric CH_4 CH_4 emissions Nitrate leaching through soil profile Ammonia volatilization from soil	(g C-CH_4 m^{-2} d^{-1}) (g C-CH_4 m^{-2} d^{-1}) (µg N-NO_3 $m^{-2}d^{-1}$) (µg N-NH_3 $m^{-2}d^{-1}$)

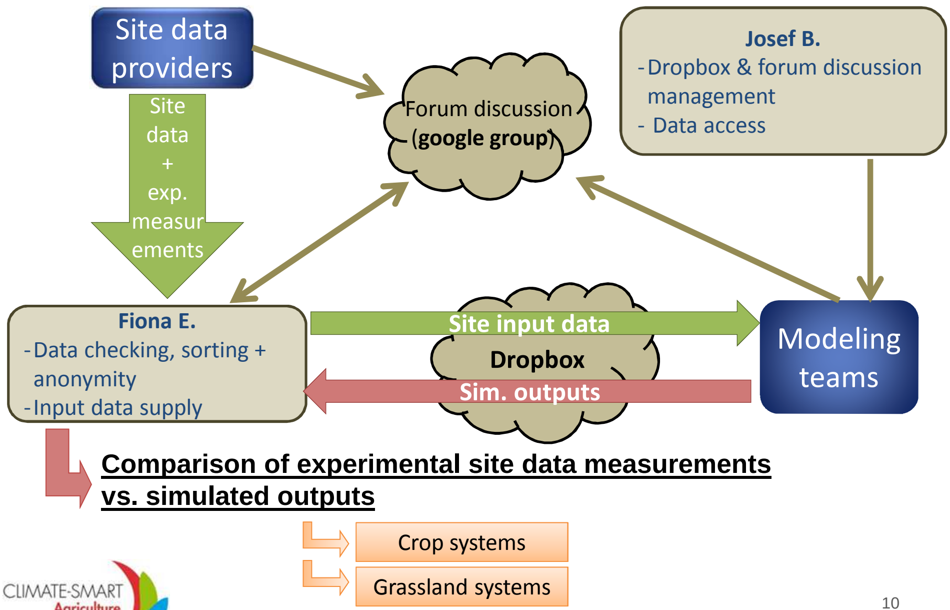
Protocol : Successive tests in model benchmarking and calibration



Blind test : initial site inputs data

- Site description
  country, latitude N, elevation, slope, aspect, albedo, field area
- Climate
  daily precipitation, temperature, solar radiation wind speed, vapor pressure, $NH3_{atm}$, $CO2_{atm}$
- Soil initial data for each layer
  depth, physicochemical description
- Management : cropland ; grassland
  cultivar, crop history, tillage, crop residues ; grazing /mowing management
- Grassland vegetation description
- Fertilization
  dates and types
- Irrigation

Blind test : data exchange system



How to compare observed vs. simulated data?

Performance against the metrics

- R^2, Coefficient of determination
- d, index of agreement
- RRMSE, Relative root mean square error
- EF, Modelling efficiency
- P(t), Paired Student t-test probability of means being equal

Analysis

- Visualizing model performance
  - Line plots of measured against modelled data
  - Boxplots
- Data aggregation
  - All seasons in one site.
  - Sites.
  - Seasons with particular crop across all sites.

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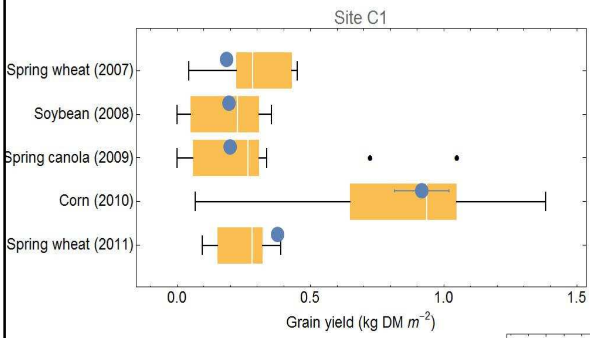
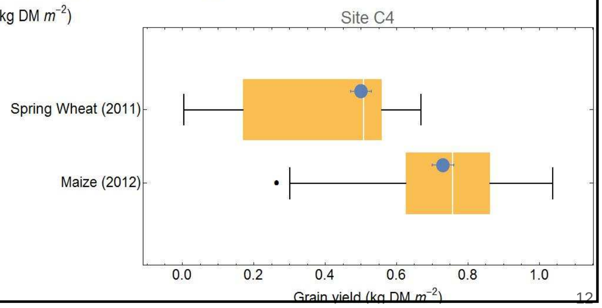
Seasonal boxplots for *grain yield*

Examples at seasonal scale – *Step 1 - Sites C1 & C4*



- Boxplots represent the simulated yield from an ensemble of models at step 1 (without any prior information)

● Observed yield per crop type



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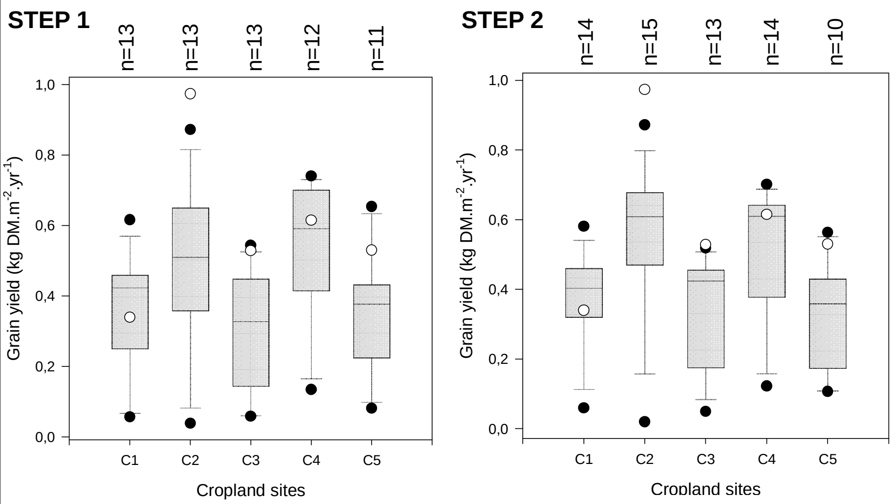
All seasons boxplots for *grain yield*

Steps 1 & 2 - Cropland sites



Simulated mean annual grain yield from an ensemble of models
○ Observed mean annual grain yield

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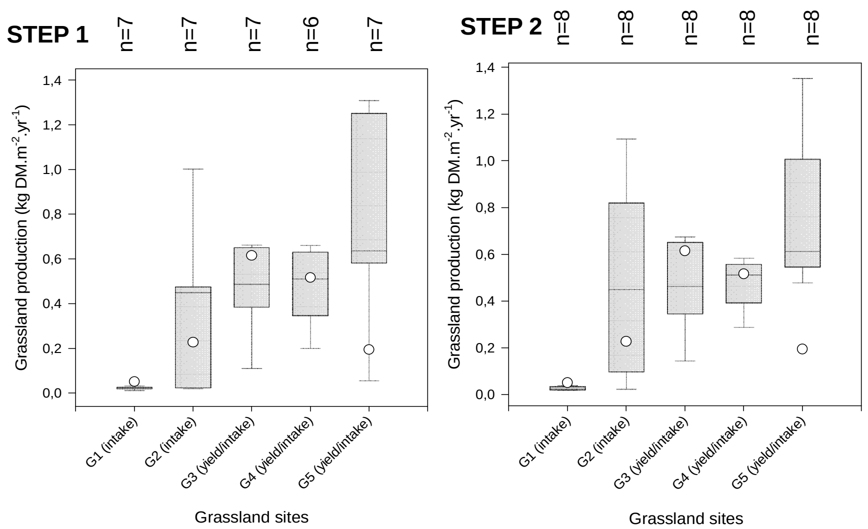
All seasons boxplots for *grassland production*

Steps 1&2 at grassland sites



Simulated mean annual grassland production from an ensemble of models
○ Observed mean annual grassland production

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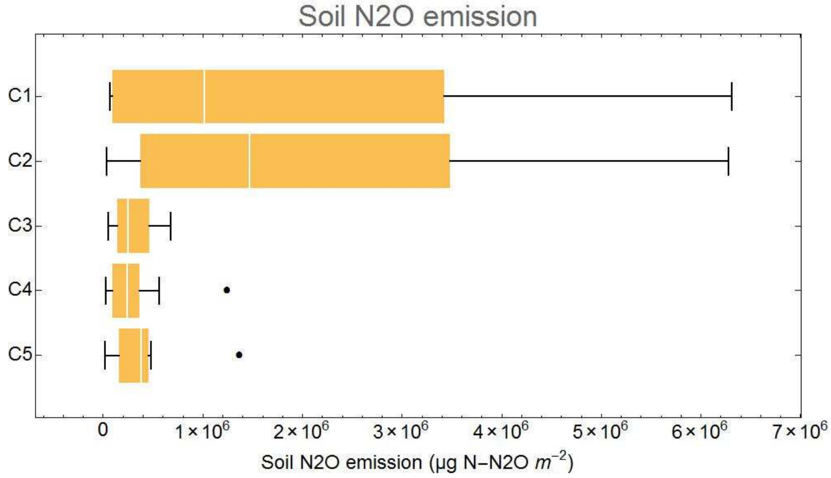
A summary of *soil N_2O emissions*

Cropland sites at step1



- Boxplots represent the mean daily simulated N_2O emissions from an ensemble of models * nb days covering the whole period of simulation

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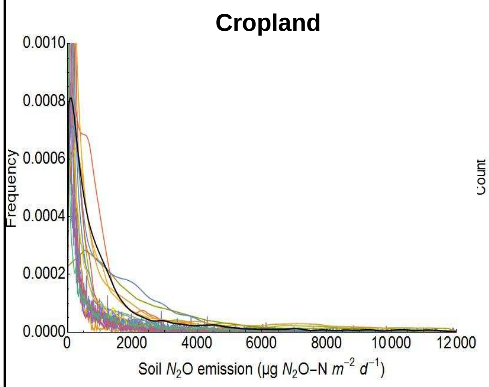
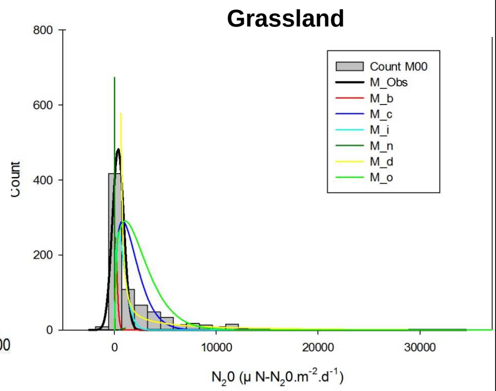
Simulated vs. observed *N_2O distribution frequency*

Examples at 1 crop site and 1 grassland site





→ N_2O peak magnitude and peak frequency prediction is difficult

→ Large variability in the shapes of simulated distribution frequencies (gaussian, log-normal, Weibull and negative exponential laws…)

→ Observed N_2O uptake (negative emission values) are not captured by models.

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Take home messages

→ *Largest benchmarking exercise* on grassland and crop systems for GHG emissions and removals;

→ Gradual calibration : *Blind:* step1 ; *model initialization* : step2 ; *model calibration*: steps 3, 4, 5 ;

→ *Improvement* of site specific predictions and ultimately *models performance*

→ Production of *guide users* on which model to use for which purpose

→ *Set standards* for new models to meet

→ Test *mitigation options* as a final goal on both gas emissions and food production.

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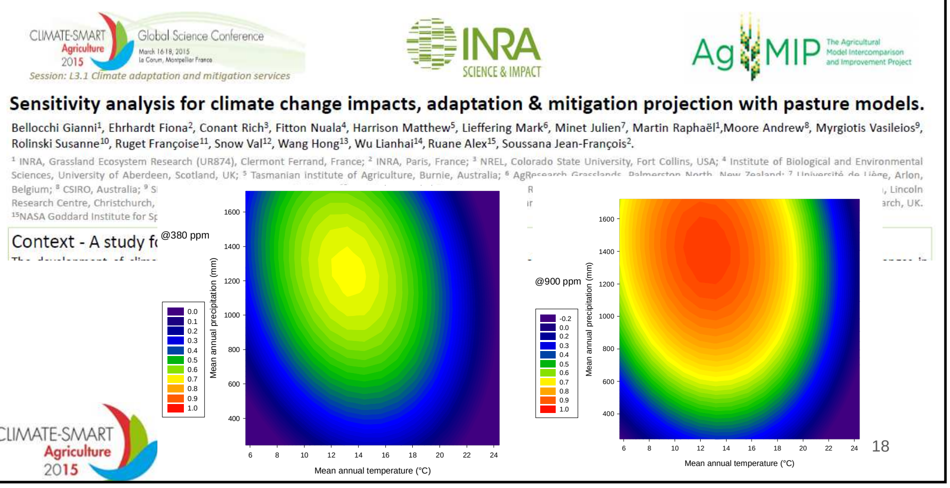
See also poster (n°21) on

Grassland production and GHG sensitivity to climate change with an exercise adapted from the Coordinated Climate-Crop Modeling Project (C3MP, AgMIP)



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Thank you for your attention

Visit our webpage :

http://www.globalresearchalliance.org/research/soil-carbon-nitrogen-cycling-cross-cutting-group/

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