CLIMATE-SMART Agriculture 2015 Global Science Conference March 16-18, 2015 Le Corum, Montpellier France

Climate Smart Agriculture Conference Montpellier (France), 16-18 March 2015.

I. Oral presentation : Model intercomparison on agricultural GHG emissions

The inter-comparison exercise has been presented at the Climate Smart Agriculture Conference, held in Montpellier from 16-18 March 2015, in the frame of the Session L3.1*: Climate adaptation and mitigation services.* The abstract with the associated PDF version of the PowerPoint are available below.

Note that the observed values for N_2O have been hidden for this version and that the figures for production (grain yield for crops and grassland production) are not the definitive ones (results extracted on 13.03.15) since modelling teams have updated their results in between, following the steering committee request.

<u>Reference</u>

Ehrhardt F, Soussana J-F, Grace P, Recous S, Snow V, Bellocchi G, Beautrais J, Easter M, Liebig M, Smith P, Celso A, Bhatia A, Brilli L, Conant R, Deligios P, Doltra J, Farina R, Fitton N, Grant B, Harrison M, Kirschbaum M, Klumpp K, Léonard J, Lieffering M, Martin R, Massad RS, Meier E, Merbold L, Moore A, Mula L, Newton P, Pattey E, Rees B, Sharp J, Shcherback I, Smith W, Topp K, Wu L, Zhang W. 2015. An international intercomparison & benchmarking of crop and pasture models simulating GHG emissions and C sequestration. In: Towards Climate-Smart Solutions L3.1 Climate, adaptation and mitigation services, Climate-Smart Agriculture, 16-18 March 2015: Montpellier, p. 41.

II. Poster session : Grasslands sensitivity analysis to climate change

The Grassland subgroup of the AgMIP *Grassland & Livestock group* has started to analyze the grassland sensitivity to climate change by adapting the C3MP protocol (see http://www.agmip.org/c3mp/). A poster has been presented at the CSA 15 (s*ession: L3.1 Climate adaptation and mitigation services),* presenting the ensemble of models that have contributed to the sensitivity analysis for temperate grassland systems.

A *meta-emulator* for the estimation of the relative changes, respectively in grassland production and N_2O emissions, has been calculated resulting in surface responses in the Temperature (°C) and Precipitation (mm) dimensions at CO_2 extreme levels of the 99 scenarios (380 and 900 ppm).

Global maps showing the relative changes in respectively, grassland production and N_2O emissions under future climatic scenarios (2050s RCP 4.5, 2050s RCP 8.5) compared to current climate (1980-2009) can be produced from the site-specific emulators.

<u>Reference</u>

Bellocchi, G., Ehrhardt, F., Soussana, J.-F., Conant, R., Fitton, N., Harrison, M., Lieffering, M., Minet, J., Martin, R., Moore, A., Myrgiotis, V., Rolinski, S., Ruget, F., Snow, V., Wang, H., Wu, L., 2015. Sensitivity analysis for climate change impacts, adaptation and mitigation projection with pasture models. In: Towards Climate-Smart Solutions L3.1 Climate, adaptation and mitigation services, Climate-Smart Agriculture, 16-18 March 2015: Montpellier, p. 110.

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

Ehrhardt Fiona[1], Soussana Jean-François[1], Grace Peter[2], Recous Sylvie[3], Snow Val[4], Bellocchi Gianni[5], Beautrais Josef[6], Easter Mark[7], Liebig Mark[8], Smith Pete[9], Celso Aita[10], Bhatia Arti[11], Brilli Lorenzo[12], Conant Rich[7], Deligios Paola[13], Doltra Jordi[14], Farina Roberta[15], Fitton Nuala[9], Grant Brian[16], Harrison Matthew[17], Kirschbaum Miko[18], Klumpp Katja[5], Léonard Joël[19], Lieffering Mark[6], Martin Raphaël[5], Massad Raia Sylvia[20], Meier Elizabeth[21], Merbold Lutz[22], Moore Andrew[21], Mula Laura[13], Newton Paul[21], Pattey Elizabeth[16], Rees Bob[23], Sharp Joanna[24], Shcherback Iurii[2], Smith Ward[16], Topp Kairsty[23], Wu Lianhai[25], Zhang Wen[26]

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The development of climate mitigation services partly depends on our ability to simulate, with confidence, agricultural production and greenhouse gas (GHG) emissions so as to understand the effectiveness of the mitigation approach on both gas emissions and food production. The Soil C-N Group of the Global Research Alliance (GRA) on GHG has initiated an international model benchmarking and inter-comparison that will assess GHG balance and soil C sequestration of arable crops and grasslands as affected by agricultural practices. The inter-comparison arises from collaborations between GRA, AgMIP and four FACCE-JPI projects to lead to the largest exercise in this domain. An initial stock take has been conducted, resulting in the selection of datasets from five grasslands and five crop sites worldwide. A total of 28 models used in 11 countries for the prediction of GHG emissions in crop and grassland systems are contributing, ranging from process-oriented models to simpler models. The study has been set up with five successive steps that gradually release information to the modeling groups ranging from fully-blind application of the models to complete availability of the experimental measurements. Model simulations are compared to experimental measurements for crop yield and grassland dry-matter production, N_2O emissions, soil C stocks and net CO_2 exchanges. The precision and accuracy of the predictions are evaluated at each step of the inter-comparison with statistical methods, facilitating quantification of projection uncertainties. Results from the first step on N_2O emissions with no prior information show variability between model predictions for any site and that model error tends to be conserved across sites. Moreover, the frequency distribution of N_2O emissions already provides an understanding of model functioning in terms of N_2O peak prediction. Further steps will allow for improved site-specific prediction and, as a final step, will expose the measured GHG emissions for model improvement.

Ehrhardt F, Soussana J-F, Grace P, Recous S, Snow V, Bellocchi G, Beautrais J, Easter M, Liebig M, Smith P, Celso A, Bhatia A, Brilli L, Conant R, Deligios P, Doltra J, Farina R, Fitton N, Grant B, Harrison M, Kirschbaum M, Klumpp K, Léonard J, Lieffering M, Martin R, Massad RS, Meier E, Merbold L, Moore A, Mula L, Newton P, Pattey E, Rees B, Sharp J, Shcherback I, Smith W, Topp K, Wu L, Zhang W. 2015. An international intercomparison & benchmarking of crop and pasture models simulating GHG emissions and C sequestration. In Towards Climate-Smart Solutions L3.1 Climate, adaptation and mitigation services (http://csa2015.cirad.fr/var/csa2015/storage/fckeditor/file/L3%20Towards%20Climate-smart%20Solutions(1).pdf, accessed 25 March 2015), Climate-Smart Agriculture, 16-18 March 2015: Montpellier, p. 41.

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Global Science Conference

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

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Institutions involved: INRA, France; Queensland University of Technology, Australia; AgResearch, New Zealand; NREL, Colorado State University, USA; USDA Agricultural Research Service, USA; University of Aberdeen, UK; Federal University of Santa Maria, Brazil; Indian Agricultural Research Institute, India; University of Florence, Italy; University of Sassari, Italy; Cantabria Agricultural Research and Training Centre, Spain; Research Centre for the Soil-Plant System, Italia; Agriculture and Agri-Food Canada, Canada; Tasmanian institute of Agriculture, Australia; Landcare Research, New Zealand; CSIRO, Australia; ETH Zurich, Switzerland; SRUC Edinburgh Campus, UK; New Zealand Institute for Plant & Food Research, New Zealand; Department of Sustainable Soil Science and Grassland System, Rothamsted Research, UK; Institute of Atmospheric Physics, China.

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Montpellier March 16-18, 2015

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

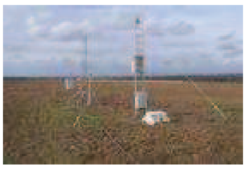
→ Experimental site (grassland or crop including *wheat*)

→ 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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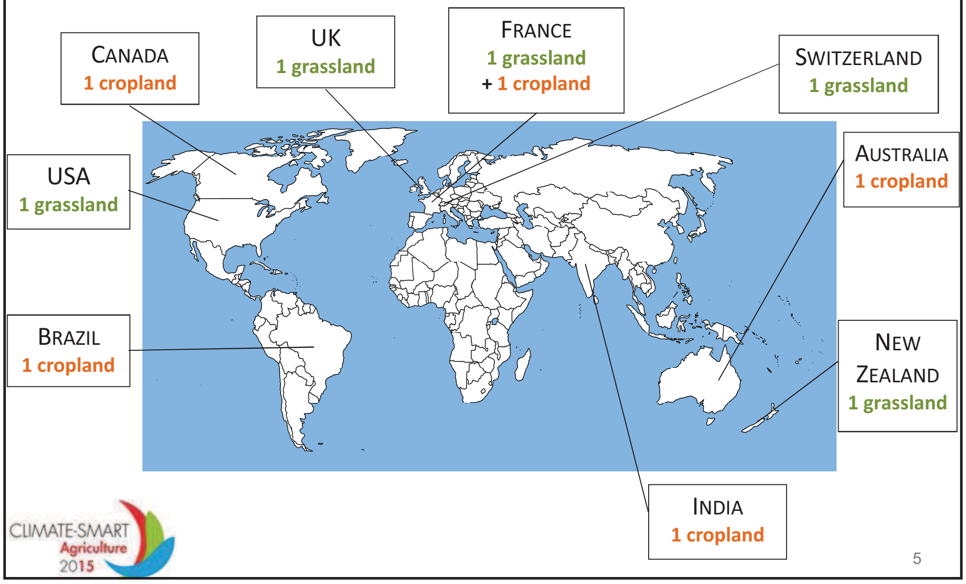
10 sites selected for model inter-comparison



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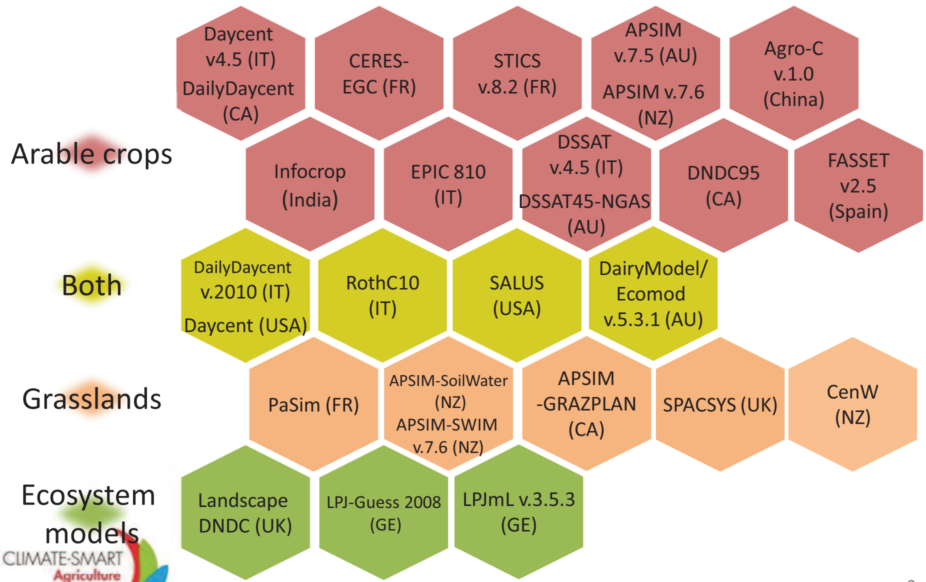
28 models from 11 countries

from process-oriented models to simpler models



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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 $m^{-2}d^{-1}$)

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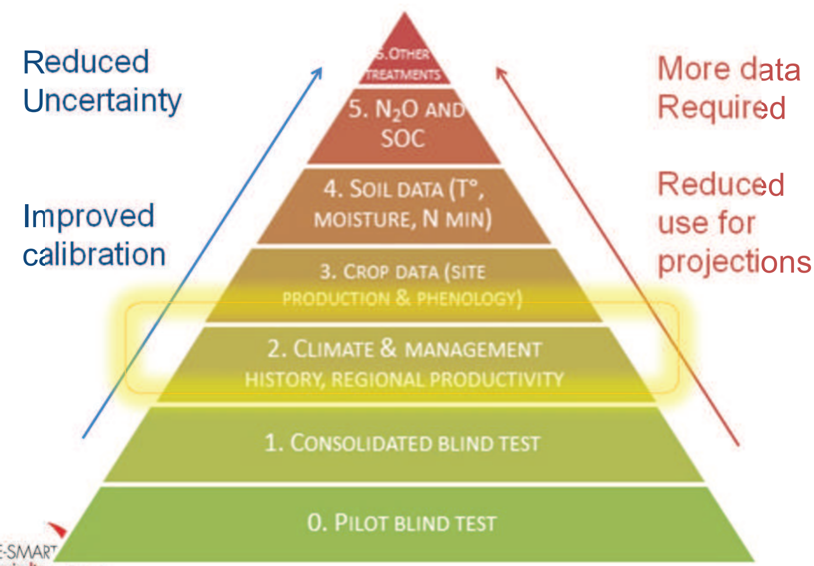
7

Protocol : Successive tests in model benchmarking and calibration



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8

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

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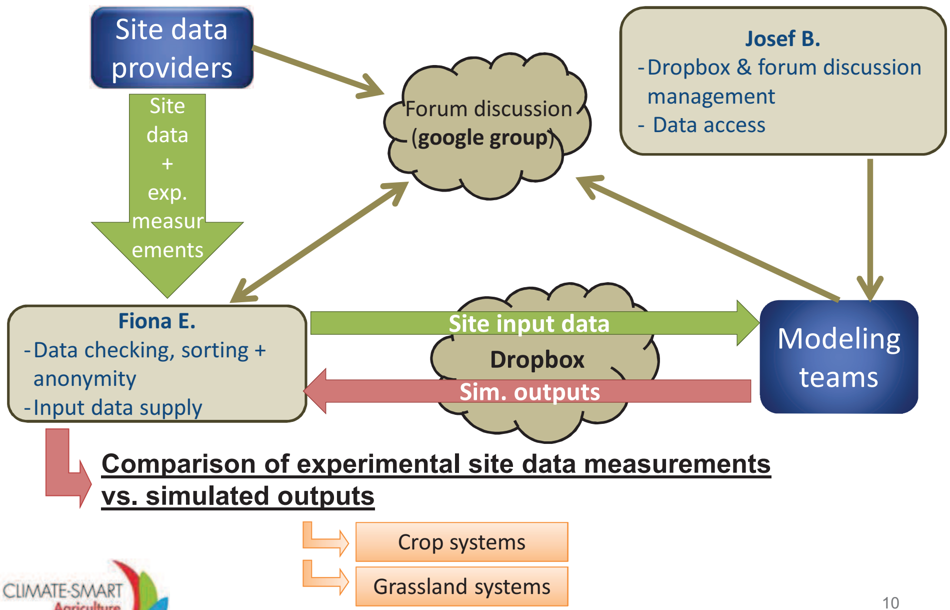
Blind test : data exchange system



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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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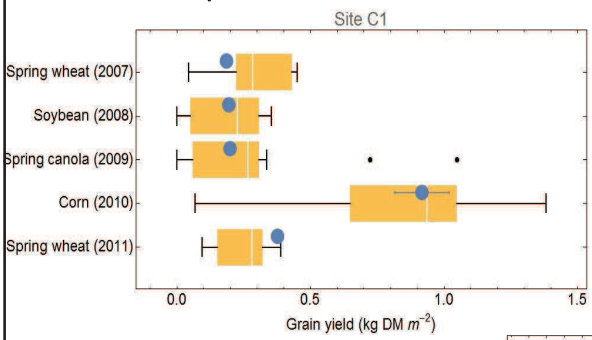
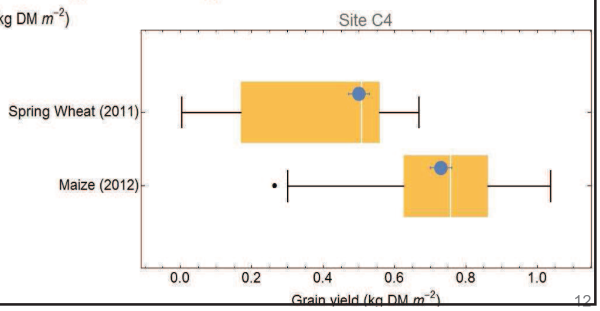
Seasonal boxplots for *grain yield*

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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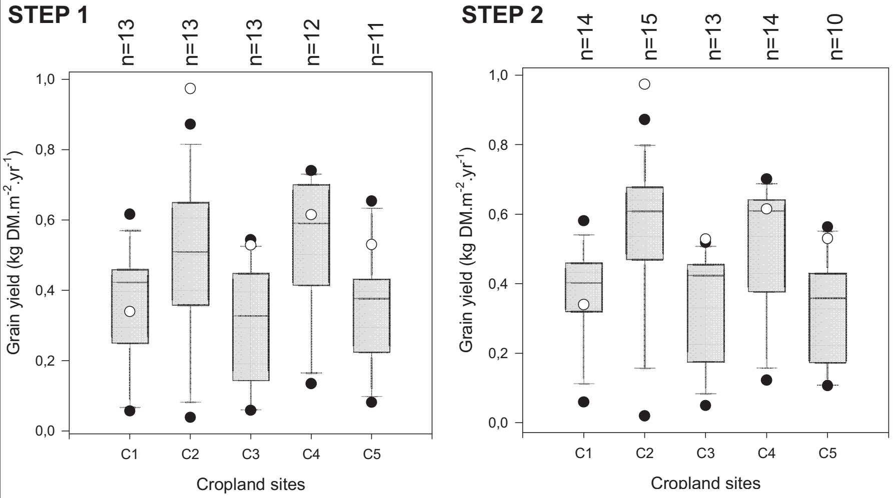
All seasons boxplots for *grain yield*

Steps 1 & 2 - Cropland sites



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

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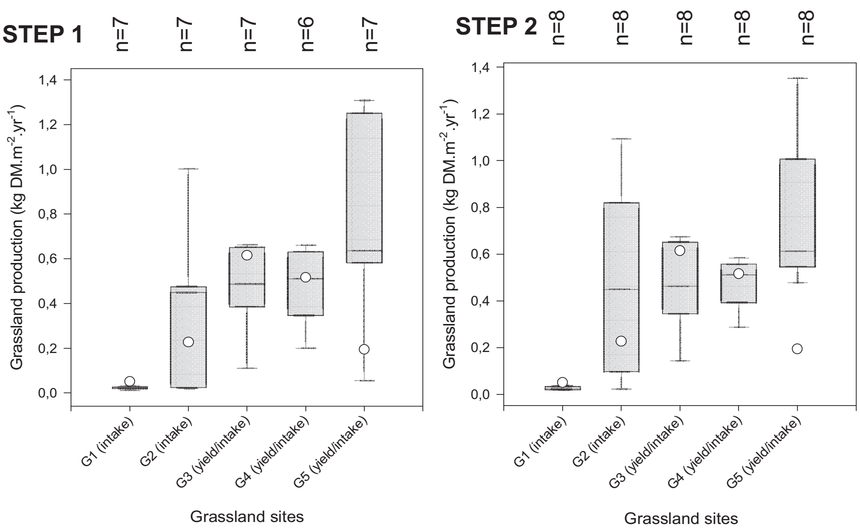
All seasons boxplots for *grassland production*

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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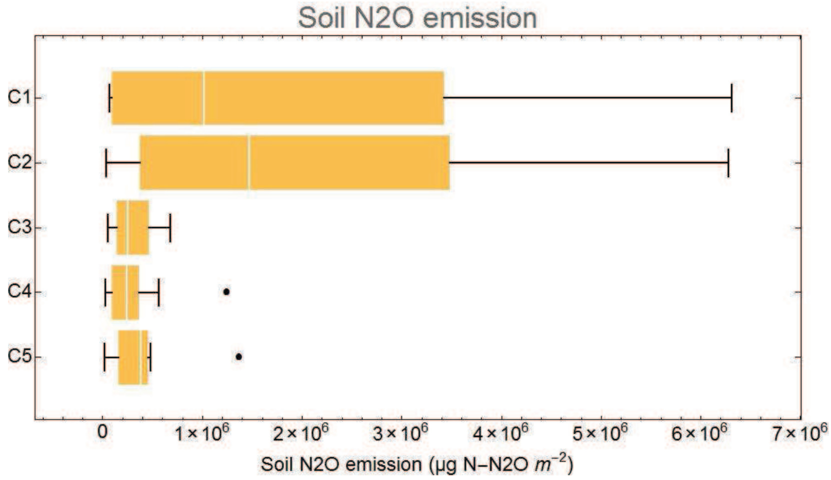
A summary of *soil N_2O emissions*

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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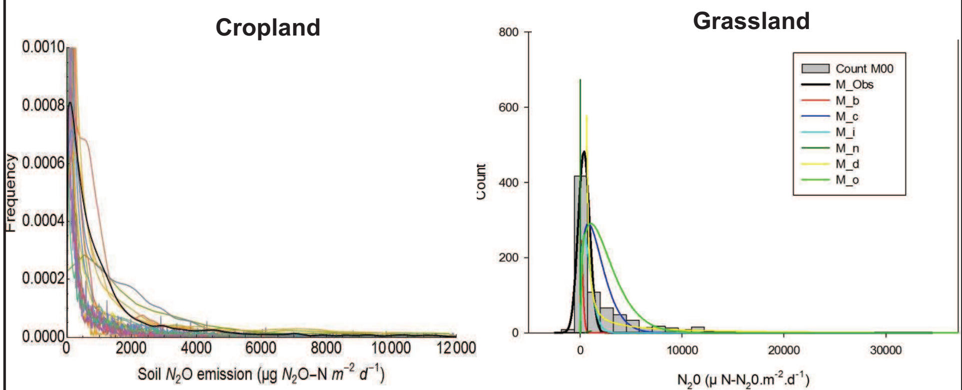
Simulated vs. observed *N_2O distribution frequency*

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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16

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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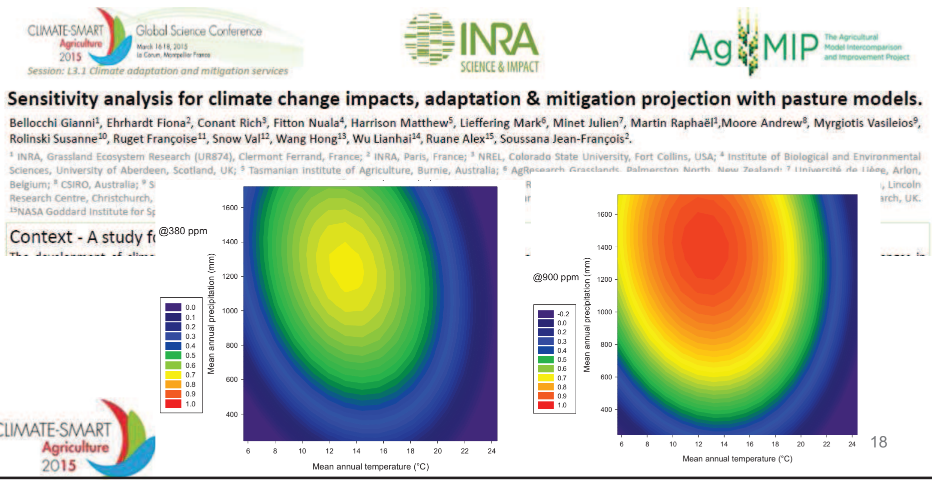
See also poster (n°21) on

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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Sensitivity analysis for climate change impacts, adaptation and mitigation projection with pasture models

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[9]*SRUC Edinburgh Campus, Scotland, United Kingdom*
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The development of climate adaptation services requires an improved accuracy in model projections for climate change impacts on pastures. Moreover, changes in grassland management need to be tested in terms of their adaptation and mitigation potential. Within AgMIP (Agricultural Model Intercomparison and Improvement Project), based on the C3MP protocol for crops, we explore climate change impacts on future greenhouse gas emissions and removals in temperate grassland systems. Site calibrated models are used to provide projections under probabilistic climate change scenarios, which are defined by a combination of air temperature, precipitation and atmospheric CO_2 changes. This design provides a test of yield, greenhouse gas emissions (N_2O and CH_4) and C sequestration sensitivity to climate change drivers. Moreover, changes in animal stocking density and in grazing *vs*. cutting are explored to test potential mitigation and adaptation options. This integrated approach has been tested for 12 models applied to 19 grassland sites over three continents and is seen as a pre-requisite for the use of models in the development of climate adaptation and mitigation services for grazing livestock.

Bellocchi, G., Ehrhardt, F., Soussana, J.-F., Conant, R., Fitton, N., Harrison, M., Lieffering, M., Minet, J., Martin, R., Moore, A., Myrgiotis, V., Rolinski, S., Ruget, F., Snow, V., Wang, H., Wu, L., 2015. Sensitivity analysis for climate change impacts, adaptation and mitigation projection with pasture models. In Towards Climate-Smart Solutions L3.1 Climate, adaptation and mitigation services (http://csa2015.cirad.fr/var/csa2015/storage/fckeditor/file/L3%20Towards%20Climate-smart%20Solutions(1).pdf, accessed 25 March 2015), Climate-Smart Agriculture, 16-18 March 2015: Montpellier, p. 110.

Session: L3.1 Climate adaptation and mitigation services

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Context - A study for temperate grassland systems

The development of climate adaptation services requires an improved accuracy in model projections for climate change impacts on pastures. Moreover, changes in grassland management need to be tested in terms of their adaptation and mitigation potential. Within AgMIP (*Agricultural Model Intercomparison and Improvement Project),* based on the C3MP protocol for crops, we explore climate change impacts on grassland production, future greenhouse gas emissions and removals in temperate grassland systems. *Key words: Climate change, Pasture, Carbon, Greenhouse gas, Soil, Livestock.*

Methodology - An exercise adapted from C3MP (Coordinated Climate-Crop Modeling Project), AgMIP

- 16 contrasted grassland sites were used covering a large climate gradient over 3 continents (mean annual temperature T from 7 to 14°C; mean annual precipitation P from 380 to 1380 mm)
- Model simulations of grassland systems using 99 combinations of climate drivers {Temperature, Precipitation, CO_2} to explore yield and GHG responses to climate change.
- Calibrated models on specific sites & global models on a set of common sites.
- Grassland management considered for simulation: no N-limitation, no irrigation, cutting events.
- Target outputs : Yields, GPP, NPP, net above-ground primary production, net herbage accumulation, SOC stock, SON stock, N2O emissions

Combinations site/model : 16 sites – 8 models

Model	Country	T	P
DairyMod v5.3.0	Australia	13,7	1024
DairyMod v5.3.0	Australia	11,7	1134
APSIM-GRAZPLAN v7.5	Australia	12,9	756
APSIM-GRAZPLAN v7.5	Australia	16,5	491
DairyMod v5.3.0	Australia	13,5	750
PaSim	Switzerland	10,3	1150
LPJmL	Switzerland	10,3	1150
PaSim	France	6,7	1071
LPJmL	France	6,7	1071
STICS v8.3.1	France	12,0	784
STICS v8.3.1	France	9,7	879
STICS v8.3.1	France	13,9	648
APSIM v7.6	New Zealand	13,4	910
APSIM-SWIM	New Zealand	11,1	714
Daily Daycent	United Kingdom	8,8	1383
Daily Daycent	United Kingdom	9,8	1343
Daily Daycent	United Kingdom	9,8	1343
Daycent	United States	8,4	378
Daycent	United States	8,4	378

Calculation of an emulator for yield & N_2O emissions

1/Determination of a global equation for yield by using a regression and {T, P, CO2} terms (= emulator):

$$Y\,(CO_2,\,T,\,P) = a + b(\mathrm{T}) + c(\mathrm{T})^2 + d(\mathrm{P}) + e(\mathrm{P})^2 + f(\mathrm{CO_2}) + g(\mathrm{CO_2})^2 + h(\mathrm{T^*P}) + i(\mathrm{T^*CO_2}) + j(\mathrm{P^*CO_2}) + k(\mathrm{T^*P^*CO_2})$$

2/Determination of the final equation for temperate grassland yield estimation by using a backward stepwise regression

3/Projection of the surface equation in {T, P, CO_2} dimensions

Results – Site specific sensitivity of grasslands annual production to climatic drivers (Illustrative example for site Ellinbank Dairy research institute, Australia, DairyMod).

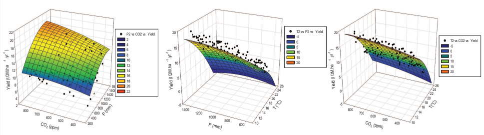
Site specific emulator calculated with 99 scenarios. Temperature changes from -1°C to +8°C, precipitation changes from -50% to +50%, CO_2 concentration from 380 ppm to 900 ppm.

Each dot represents an individual run. The mesh curve was fitted with the emulator calculated as described ($n=99$; $r^2=0.995$, $P<0.001$).

1/ **T*P*Yield** ; CO_2 = 380 ppm

2/ **T* CO_2 *Yield** ; local mean P (mm)

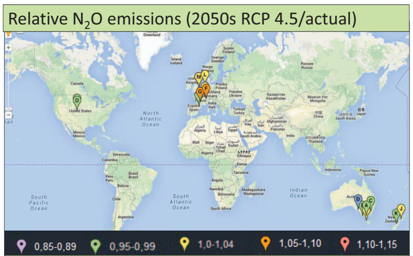
3/ **P* CO_2 *Yield** ; local mean T (°C)



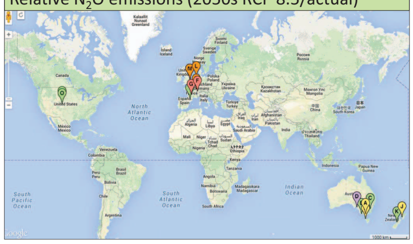
Relative Yield (2050s RCP 4.5/actual)

Relative Yield (2050s RCP 8.5/actual)

Relative N_2O emissions (2050s RCP 4.5/actual)



Relative N_2O emissions (2050s RCP 8.5/actual)

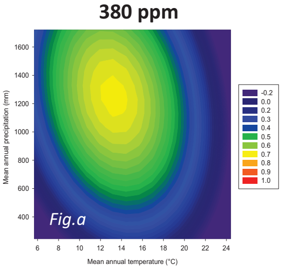


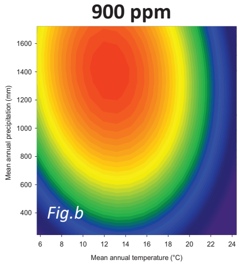
Sensitivity of temperate grasslands production & N_2O emissions to climatic drivers from an ensemble of models

380 ppm

900 ppm

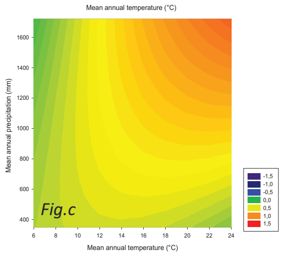
Yield

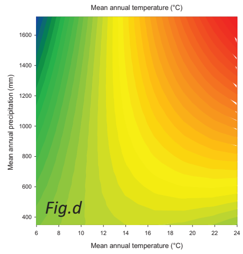




Mean surface response of temperate grasslands **annual production** to climatic drivers ($n=1089$; $r^2 = 0.64$, $P<0.001$). Production changes were calculated relative to climate conditions leading to maximum production, under 380 ppm (*Fig.a*) and 900 ppm (*Fig.b*).

N_2O





Mean surface response of temperate grasslands **N_2O emissions** to climatic drivers ($n=891$; $r^2 = 0,296$, $P<0.001$). Production changes were calculated relative to climate conditions leading to maximum N_2O emissions, under 380 ppm (*Fig.c*) and 900 ppm (*Fig.d*).

Extension to global maps for grassland systems

Relative changes in grassland production and N_2O emissions under future climatic scenarios (2050s RCP 4.5, 2050s RCP 8.5) compared to current climate (1980-2009) were projected from the emulator for all sites. Results show that without N limitation, production and N_2O emissions mostly increases by the 2050's. Elevated CO_2 (ca. 600 ppm in both RCPs) plays a large role in this increase and this questions the extent to which models may overestimate this CO_2 effect (e.g. for P limited grasslands). The use of an emulator provides a fast-track to upscale simulations for global grasslands and test a large range of climate scenarios, as well as adaptation and mitigation options. By extending the methodology to tropical grassland systems and rangelands, global maps for the variation of production, carrying capacity and GHG emissions could be generated for the grassland biome.