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

Gianni Bellocchi, Fiona Ehrhardt, Conant Rich, Fitton Nuala, Harrison Matthew, Lieffering Mark, Julien Minet, Raphaël Martin, Andrew Moore, Vasileios Myrgiotis, et al.

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

Session: L3.1 Climate adaptation and mitigation services

INRA SCIENCE & IMPACT

AgMIP The Agricultural Model Intercomparison and Improvement Project

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

Bellocchi Gianni[1], Ehrhardt Fiona[2], Conant Rich[3], Fitton Nuala[4], Harrison Matthew[5], Lieffering Mark[6], Minet Julien[7], Martin Raphaël[1],Moore Andrew[8], Myrgiotis Vasileios[9], Rolinski Susanne[10], Ruget Françoise[11], Snow Val[12], Wang Hong[13], Wu Lianhai[14], Ruane Alex[15], Soussana Jean-François[2].

[1] INRA, Grassland Ecosystem Research (UR874), Clermont Ferrand, France; [2] INRA, Paris, France; [3] NREL, Colorado State University, Fort Collins, USA; [4] Institute of Biological and Environmental Sciences, University of Aberdeen, Scotland, UK; [5] Tasmanian institute of Agriculture, Burnie, Australia; [6] AgResearch Grasslands, Palmerston North, New Zealand; [7] Université de Liège, Arlon, Belgium; [8] CSIRO, Australia; [9] SRUC Edinburgh Campus, Scotland, UK; [10] Potsdam Institute for Climate Impact Research, Germany; [11] INRA, UMR EMMAH, Avignon, France; [12] AgResearch, Lincoln Research Centre, Christchurch, New Zealand; [13] Agriculture and Agri-Food Canada, Saskatoon, Canada; [14] Department of Sustainable Soil Science and Grassland System, Rothamsted Research, UK. [15]NASA Goddard Institute for Space Studies, Climate, Impacts Group, New York, NY, United States of America.

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

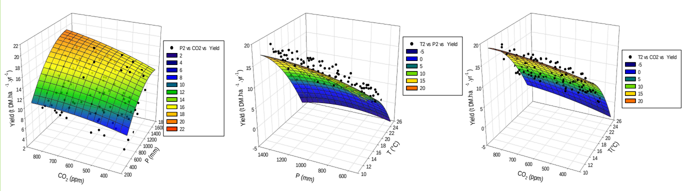
3/Projection of the surface equation in {T, P, CO_2} dimensions

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

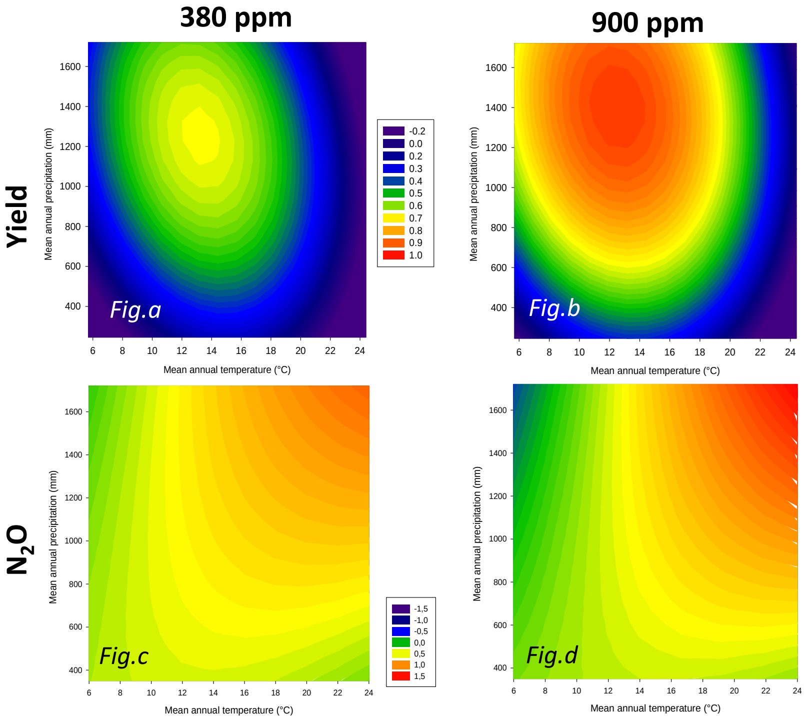
Site specific emulator calculated with 99 scenarios. Temperature changes from -1°C to +8°C, precipitation changes from -50% to +50%, CO_2 concentration from 380 ppm to 900 ppm.

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)



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



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*).

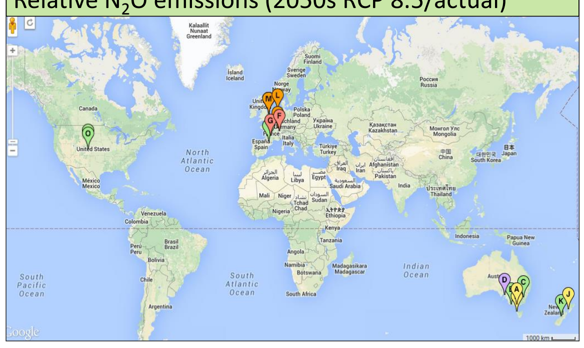
Mean surface response of temperate grasslands **N_2O emissions** to climatic drivers (n=891 ; r^2 = 0,296, P<0.001).
Production changes were calculated relative to climate conditions leading to maximum N_2O emissions, under 380 ppm (*Fig.c*) and 900 ppm (*Fig.d*).

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)



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.