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

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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
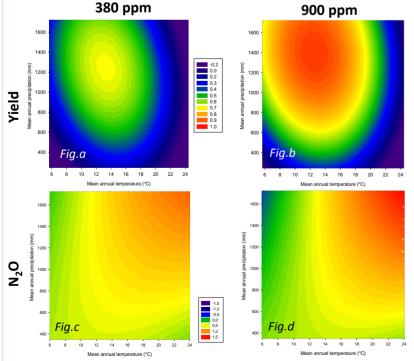
### Combinations site/model : 16 sites – 8 models

| 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):

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

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)

0,9-0,99 | 1,0-1,09 | 1,10-1,19 | 1,20-1,39 | >1,5

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



**380 ppm** — **900 ppm**

Fig.a — Fig.b

Yield

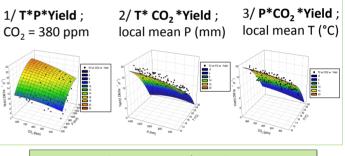Mean surface response of temperate grasslands **annual production** to climatic drivers (n=1089 ; $r^2$ = 0.64, P<0.001). Production changes were calculated relative to climate conditions leading to maximum production, under 380 ppm (*Fig.a*) and 900 ppm (*Fig.b*).

Fig.c — Fig.d

N2O

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 $N_2O$ emissions (2050s RCP 4.5/actual)

0,85-0,89 | 0,95-0,99 | 1,0-1,04 | 1,05-1,10 | 1,10-1,15

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.