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To cite this version:
Anne-Isabelle Graux, Romain Lardy, Gianni Bellocci, Jean-François Soussana. Global warming potential from French grassland / livestock systems. Colloque ACCAE - Adaptation au Changement Climatique de l’Agriculture et des Ecosystèmes, Institut National de Recherche Agronomique (INRA). UR Unité de recherche sur l’Ecosystème Prairial (0874)., Oct 2010, Clermont-Ferrand, France. hal-02754299

HAL Id: hal-02754299
https://hal.inrae.fr/hal-02754299
Submitted on 3 Jun 2020

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Global warming potential from French grassland / livestock systems

Anne-Isabelle Graux
Romain Lardy, Gianni Bellocchi, Jean-François Soussana
(INRA - French National Institute for Agricultural Research)

Clermont-Ferrand (France), October 2010, 20-22
Global warming potential (GWP) is a measure of how much a given mass of greenhouse gas (GHG) contributes to global warming. Equal to 1 for CO\textsubscript{2}, GWP is calculated by adding CH\textsubscript{4} and N\textsubscript{2}O emissions to the net ecosystem exchange (NEE) values (IPCC, 2007a):

\[ GWP = k_{N_2O} \cdot N_2O + k_{CH_4} \cdot CH_4 - NEE \]

- A positive GWP indicates a net source of GHG to the atmosphere and conversely
- Of the three GHG exchanged by grasslands, CO\textsubscript{2} is exchanged with soil and vegetation, N\textsubscript{2}O is emitted by soils, and CH\textsubscript{4} is emitted by livestock at grazing
Grassland / livestock systems & Global warming / 2

Grassland / livestock systems differ for their impact on the magnitude of GHG fluxes and their GWP (FAO, 2006)

- Livestock systems generate 18% of global GHG emissions, with considerable variability depending on both the animal (breed, age, kind of production, physiological stage, etc.) and the diet (level of intake, forage / concentrate proportion, feed processing, etc.)
- Combined effects of elevated CO$_2$ and climate change may enhance net primary production and carbon (C) stocks, reducing GHG emissions by sequestering C in the soils

A model-based study was employed to simulate prospective changes and feedbacks between grassland / animal performances and GWP in France
An array of scenarios was sketched to represent climate-soil-plant-management interactions under climate changes and CO₂ enrichment in France.

<table>
<thead>
<tr>
<th>Management</th>
<th>Sown Irrigated (SI)</th>
<th>Rainfed (S)</th>
<th>Permanent Intensive (PI)</th>
<th>Extensive (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation</td>
<td>monoculture 100% <em>Lolium perenne</em> L.</td>
<td>320</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>multispecies 20% <em>Trifolium repens</em> L.</td>
<td>80</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fertilization (kg N ha⁻¹)</td>
<td></td>
<td>April 15</td>
<td>April 15</td>
<td></td>
</tr>
<tr>
<td>Irrigation (% of needs)</td>
<td></td>
<td>June 30</td>
<td>June 01</td>
<td></td>
</tr>
<tr>
<td>Cutting dates</td>
<td></td>
<td>August 15</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Grazing periods</td>
<td></td>
<td>October 15</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Stocking density (Livestock unit ha⁻¹)</td>
<td></td>
<td>-</td>
<td>July 20 to August 05</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>October 15 to November 01</td>
<td>0.8</td>
</tr>
</tbody>
</table>
The simulation study / 2

Projections of climate conditions of near future (2020-2049) and far future (2070-2099) were generated from the Special Report on Emission Scenarios (SRES) by the Intergovernmental Panel on Climate Change (IPCC)...

<table>
<thead>
<tr>
<th>SRES</th>
<th>GCM</th>
<th>Institute</th>
<th>Downscaling method</th>
<th>Initialization</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>ARPEGE</td>
<td>CNRM</td>
<td>Variable corrections (VC)</td>
<td></td>
</tr>
<tr>
<td>A1B</td>
<td>ARPEGE</td>
<td>CNRM</td>
<td>Anomalies</td>
<td></td>
</tr>
<tr>
<td>A1B</td>
<td>ARPEGE</td>
<td>CNRM</td>
<td>VC</td>
<td></td>
</tr>
<tr>
<td>A1B</td>
<td>ARPEGE</td>
<td>CNRM</td>
<td>Statistical disaggregation (SD) 1</td>
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<tr>
<td>A1B</td>
<td>ARPEGE</td>
<td>CNRM</td>
<td>SD</td>
<td>2</td>
</tr>
<tr>
<td>A1B</td>
<td>CGCM 3.1 T63</td>
<td>CCCMA</td>
<td>SD</td>
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<tr>
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<td>NASA/GISS AOM</td>
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<td>SD</td>
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<tr>
<td>A1B</td>
<td>CGCM 2.3.a</td>
<td>MRI</td>
<td>SD</td>
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</tr>
<tr>
<td>A1B</td>
<td>CCSM 3.0</td>
<td>NCAR</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>A2</td>
<td>ARPEGE</td>
<td>CNRM</td>
<td>VC</td>
<td></td>
</tr>
</tbody>
</table>

... crossing a range of global circulation models (GCM), downscaling methods / initializations in order to encompass the whole range of uncertainty associated with current climate modelling
The Pasture Simulation Model (PASIM) was employed to generate a variety of outputs related to GWP under future (2020-2049, 2070-2099) and near past (1970-1999) climate conditions.

**INPUT**

- **Climate**
  - Radiation
  - Precipitation
  - Temperature
  - Vapor pressure
  - Wind speed
  - CO₂
  - NH₃

- **Soil**
  - Texture
  - SWC
  - Conductivity
  - Density
  - Depth

- **Vegetation**
  - Multi or monospecies
  - With or without legumes

- **Herbivores**
  - Type (heifers, suckler or dairy cows, sheeps)
  - LW, BCS, age, MP\textsubscript{pot,max}, at turnout to grass

- **Management**
  - Mowing
  - N fertilization
  - Grazing
  - Tillage

**OUTPUT**

- **Fluxes**
  - GHG (CO₂, N₂O, CH₄)
  - C, N, H₂O & energy fluxes ...

- **States**
  - Forage provision
  - MP, LW and BCS
  - SOM
  - SWC ...

- **Optimized management**
  - Mowing
  - N fertilization
  - Grazing
  - Irrigation

[https://www1.clermont.inra.fr/urep/modeles/pasim.htm](https://www1.clermont.inra.fr/urep/modeles/pasim.htm)
Changes in rainfall and air temperatures: SRES A2, ARPEGE model, variable correction downscaling

Avignon  Mirecourt
Changes in the GWP:
irrigated temporary grassland, shallow soil

Avignon

Mirecourt
Changes in the NEE:
irrigated temporary grassland, shallow soil

Avignon

Mirecourt
Changes in the $\text{N}_2\text{O}$: irrigated temporary grassland, shallow soil

Avignon

Mirecourt
Overall findings

- While there are site-to-site and climate-to-climate variations, a conclusion is that the GWP may decrease in the future as result of increased soil dryness and C storage

- All systems were observed to be net sinks of C, with temporary irrigated grasslands offering the greatest potential to mitigate GHG in the future thanks to higher NEE

- Strategies to enhance fertilizer use efficiency, animal feed and return of animal waste could be explored as adaptation & mitigation measures
Thank you for your attention!!!

Research supported by the Auvergne Region of France and by the ANR CLIMATOR project