Management and Impact of Climate Change
Programme GICC
CRP 2001

6/01 – Sources and sinks of greenhouse gases (CO_2, CH_4, N_2O) in grazed pasture land and reduction strategies

Summary of Final Report

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*The **GES-Prairies** (Greenhouse Gases – Grasslands) project has two objectives:*
1° The reduction of uncertainties regarding CO_2, CH_4 and N_2O fluxes and the assessment of the balance of these greenhouse gases in French grasslands.
2° The analysis of cattle farms net emissions, and the development and evaluation of management scenarios to reduce net emissions.
This project involves three different levels, i.e. the field, the farm and the region.

The field level
CO_2, CH_4 and N_2O fluxes were monitored for two years in a permanent hill pasture (Laqueuille, Puy-de-Dôme) that had been previously managed intensively under a dual mowing-grazing regime. As from April 2002, this area was grazed by cattle and submitted to two different treatments: intensive grazing with nitrogen fertilization (1.0 Livestock Unit LSU.ha^{-1} and 170 kg N.ha^{-1}.year^{-1}) *vs* extensive grazing (0.5 LSU.ha^{-1}) without fertilization. The balance of the first year's monitoring shows that extensification (reducing the stocking rate and stopping nitrogen fertilization) leads to greater carbon sequestration in the pasture (Net Ecosystem Exchange NEE equal to –0.38 and –1.40 t CO_2.h^{-1}.year^{-1} in intensive and extensive treatments respectively). The respiration of the cattle contributes significantly to the balance (emission of 1.0 and 1.9 t CO_2.ha^{-1}.year^{-1} respectively). Extensification did not lead to a significant increase per unit of live weight in methane emissions from the ruminants' enteric fermentation. A weak methane oxidation activity was recorded in the soils. N_2O emissions were highly variable both in space (lognormal distribution) and time; measurements reflect low mean fluxes, corresponding to a N_2O emission factor (following the IPCC methodology) of 0.50 % in the fertilized pasture. After a year's monitoring, the intensively treated pasture comes out as a net source of greenhouse gases (+0.64 t C-CO_2 equivalent.ha^{-1}.year^{-1}) whereas the extensively treated pasture clearly acts as a sink (-0.92 t C-CO_2 equivalent.ha^{-1}.year^{-1}) due to lower N_2O and CH_4 emissions and to more active CO_2 sequestration. The same trends were obtained from simulations with the PASIM model, which indicates that

pastures act as a greenhouse gas sink during the first year following a reduction of the stocking rate (extensification). The greenhouse gas balance trend in the longer term is not known, though the PASIM model suggests that the carbon sequestration rate obtained in the extensive treatment would be difficult to maintain over time without nitrogen fertilization.

The farm level

A model called FARMSIM was developed, coupled with the PASIM model, to simulate the greenhouse gas balance of a livestock farm. It was tested on a dual-purpose cattle farm (dairy and beef, with a mean annual stocking rate of 1.3 $LSU.ha^{-1}$) on 100 ha of useable farm area (including 76 ha of fields and 21 ha of annual crops) in Lorraine. Results indicate net yearly emissions of 175 t $C\text{-}CO_2$ equivalent for this farm. The greenhouse gas balance reaches 1.34 t $C\text{-}CO_2$ equivalent per LSU yearly, i.e. 0.54 kg $C\text{-}CO_2$ per kg of milk produced. Carbon sequestration in the pastures, simulated with the PASIM model, is the only carbon sink on the farm. Without this sink absorbing 56 t $C\text{-}CO_2$ equivalent, the greenhouse gas balance of the farm would be 30 % higher. Direct emissions by the cattle themselves (methane from enteric fermentation and carbon dioxide from respiration) form the greatest contribution to the farm's simulated emissions (142 t $C\text{-}CO_2$ equivalent) - methane contributing to a little over half of this. More than half of the farm's emissions of N_2O is linked to the storage of the animal waste produced in housed conditions. Although the annual crops use up only 21 ha, they produce almost as much N_2O as the grasslands. Several scenarios for the reduction of the greenhouse gas balance on this farm are currently being examined. The most promising scenario would suppress the beef production unit, replace maize by a high-protein crop, halve the nitrogen input on the pastures (relying on a greater nitrogen fixation by legumes) and increase to 85 % the proportion of grass in the winter feeding. Data from two other farms of the west of France should be soon available and will be similarly analysed.

The regional level

The PASIM model was used to simulate European pastures with a spatial resolution of 1' (approximately 200 km x 200 km). In each grid cell, a sensitivity analysis calculated the nitrogen input equivalent to 30 % of what would maximize annual growth in the pasture. Calculated inputs range from 150 to 300 $kg.ha^{-1}.year^{-1}$ in France, amounts that are in keeping with the usual management practices for hay meadows. Lower inputs are simulated for grazed pasture land (since grazing is associated with a high degree of nitrogen recycling) and for dual-purpose grasslands, in which case a combination of hay meadows and grazed pastures is calculated for each pixel, reflecting the proportions of the winter and summer feeding needs of the herds. Plant productivity in France ranges from 4 to 6 t $C.ha^{-1}.year^{-1}$, i.e. from 10 to 15 t dry $weight.ha^{-1}.year^{-1}$. Simulations concerning dual-purpose management (mowing/grazing) show that almost half the surface area, on average, is used for mowing. Simulations indicate relatively uniform N_2O emission coefficients over Europe's grid cells, with values around 1-2 % in mown grasslands (input of mineral nitrogen) and 3-4 % in grazed grasslands (input of nitrogen from animal dejections). Under a cut grass regime, simulations predict high yearly carbon sequestration, ranging between 0.5 and 6 t $C.ha^{-1}.year^{-1}$ – but part of this sequestration takes place in the collected forage (aerial parts collected). Carbon storage is thus lower in

grazed pasture land (0.3-2 t C.ha^{-1}.year^{-1}) than in mown meadows. The simulations indicate that mown grasslands constitute a significant net sink for the studied greenhouse gases, of a magnitude varying from 2.5 to 6 t C-CO_2 equivalent.ha^{-1}.year^{-1} in France. In contrast, grazed pasture land stocked to its full capacity would be a net source of greenhouse gases, with fluxes ranging between 0.5 and 2 t C-CO_2 equivalent.ha^{-1}.year^{-1}. Simulations concerning combined mown and grazed grasslands in proportions reflecting winter feeding requirements identify them as net sinks of greenhouse gases, with yearly fluxes of 2-3 t C-CO_2 equivalent.ha^{-1}.year^{-1}. A higher degree of realism could be attained by taking into account the specificities of the various animal production systems. Data from the *Institut de l'Elevage* networks are being processed in order to provide the PASIM model with input parameters concerning management obtained on a regional basis. A collaboration was launched at the European level in order to round up equivalent data concerning the main animal production systems in Europe. Regional simulations of livestock farms, their greenhouse gas balance and economic performance could eventually be run. This would provide us with sound bases for elaborating scenarios for the attenuation of greenhouse gas emissions in the livestock farming sector.