Greenhouse gas emissions on french meat sheep farms: analysis over the period 1987-2010

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GREENHOUSE GAS EMISSIONS ON FRENCH MEAT SHEEP FARMS: ANALYSIS OVER THE PERIOD 1987-2010

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ABSTRACT Livestock production is seen as one of the major contributors of GHG emissions. Focusing on French meat sheep breeding systems, this study sheds light on the main factors that influence resource utilization and GHG emissions. Through a sample of 1,180 farm observations, emissions were evaluated applying the Life Cycle Assessment (LCA) method. For this purpose, a large number of input categories were analyzed including feed, fertilizers, manure and services such as insurance and banking. Specificities of farming systems located in plain and mountain areas, and systems managed in conventional and organic methods are identified. The LCA results show average gross emissions of 31.6 Kg CO_2 eq for 1 Kg of carcass. When the carbon sequestration in soils is accounted for, we obtain average net emissions of 27.9 Kg CO_2 eq per CW. CH_4 represents 61% of the total emissions, CO_2 21% and N_2O 18%. On average, for each gas the main emission factor was enteric fermentation for 77% of CH_4, feed for 33% of CO_2 and manure emissions on pasture for 61% of N_2O. Organic farms' net emissions are smaller than conventional ones by 2 Kg CO_2 eq per CW. Farms located in the mountain areas also exhibit lower net emissions than those in plain areas. Finally, increasing emission trends observed over the 24 years are discussed.

Keywords: Life Cycle Assessment, Greenhouse Gases, Sheep farming

INTRODUCTION

According to IPCC (Intergovernmental Panel on Climate Change) experts, the global climate is changing, based on rapid temperature increases recorded due the release of certain gases in the atmosphere. The quick rise of the concentration of GHG is largely related to human activity (IPCC, 2007). In this paper we are concerned with livestock, as it contributes to about 18% of GHG emissions on an international scale, a higher share than transportation (Steinfeld et al., 2006). The quantification of GHGs is widely based on Life Cycle Assessment (LCA), which is a method to assess and identify sources of environmental impacts of a product or a system from "cradle to grave". The method was applied to French meat sheep farms divided into plain and mountain systems or managed in organic and conventional methods. As the LCA methodology has been largely applied to evaluate the environmental impacts of beef, there are fewer published studies regarding lamb production (Zervas and Tsiplakou, 2012). Therefore, the aim of this paper is to contribute to better knowledge of GHG emissions on lamb production farms by comparing different systems.

1. MATERIAL AND METHODS

1.1. Data The data came from surveys conducted by the French National Institute of Agronomic Research (INRA) over the period 1987-2010. With about 49 farms per year totalling 1,180 observations over the studied period, the areas covered are North Massif Central and its periphery. The sample is not constant because of new arrivals and retirements (average presence of 11 years).

1.2. Methodology Life Cycle Analysis (LCA) is a technique now widely available and used in agriculture that provides clear and objective information on resource flows and environmental impacts associated with the provision of goods and services. This method requires defining the system boundary, the Functional Unit (FU), the Life Cycle Inventory and the allocation methods. The system boundary used for this LCA is defined by GHG emissions linked with lamb production from "cradle to farm gate". It includes all upstream processes (production of farm inputs and sheep farming) in livestock production up to the point where the animals or products leave the farm. Regarding the Functional Unit (FU), the studied sheep farms produce lamb and wool. Here we are only interested in the meat; therefore, the GHG emissions are expressed in Kg of CO_2 equivalents per Kg of carcass weight. As the sheep farms not only produce lamb but also wool, we allocated the environmental impacts between these two products. To do so, we resort to the commonly used mass allocation. Eventually, a collection of information on all activities included within the system boundary was necessary. The major GHG assessed are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). For methane and nitrous oxide we used the Global Warming Potentials (GWP) to convert these gases into CO_2 equivalents. The values of GWP are, respectively, 25 and 298. In this analysis we added the most commonly included emission sources (feeding, fertilizer, energy, machinery, buildings, enteric fermentation, and manure management). The principal tool for this evaluation was "Dia' terre ®" mainly developed by "ADEME" (Agency for Environment and Energy Management) and the Ministry of Food, Agriculture and Fisheries.

2. RESULTS AND DISCUSSION Table 1 shows main results (in CO_2 equivalents per Kg of Carcass weight) of GHG emissions for each gas and carbon sequestration. In total, 26.4 Kg CO_2 eq for 1 Kg of carcass account for direct emissions and 5.2 for indirect emissions. Methane is the most significant gas and is responsible for 61% of the gross GHG. It is followed by carbon dioxide and nitrous oxide which, respectively, share 21% and 18%. Moreover, the main contributors to each gas are for CO_2 feeds (33%), fuel (20%), fertilizer (20%) and breeding purchase (18%); for CH_4 enteric fermentation (77%) and dejections (23%); for N_2O dejections in housing and pastures (61%), runoff and leaching (20%) and mineral fertilizer (17%). The results also exhibit high variability as the mean in the first quartile group stands at 24.0 and for the last quartile group it reaches 41.6. To account for the heterogeneity in our sample, the total emissions were declined for each system: mountain or plain and organic or conventional. Table 2 presents the differences among the systems and within each system, which are highly significant. We notice that farms in mountains sequester twice more than those in plain areas (mountain farms have more permanent pastures). Organic net emissions stand at 2 Kg CO_2 eq/CW below the conventional ones. A few studies used LCA to assess the number of meat sheep farms. Based on rather optimized farming systems and with another methodology (especially for soil sequestration, Leip et al., 2010) Benoit et al. (2010) obtained 27.6 Kg CO_2 eq Kg^{-1} CW of meat as gross emissions and 13.7 for net emissions. The study conducted by the French Livestock Institute (Morin et al., 2011) on three different lamb production systems exhibited gross emissions of 18.8 Kg CO_2 eq Kg^{-1} CW of meat and 15.0 for net GHG. Estimates for GHG gross emissions in other studies (Zervas and Tsiplakou, 2012) were 12.9 Kg CO_2 eq Kg^{-1} BW (Body Weight) for lamb in Wales (Edward-Jones et al., 2009), 10.0 in Ireland (Casey and Holden, 2005), 14.1 in the United Kingdom (Williams et al., 2008), and 8.6 in New Zealand (Ledgard et al., 2010). In this country, sheep farmers use fewer inputs and breeds produce more wool, supporting a larger part of the GHG emissions. However, the comparison might be biased because of the differences in the methodology adopted by authors, system boundaries, emission factors or functional unit.

Table 1. Descriptive statistics of main results Kg CO2 eq/CW (N=1180)

	MEAN	STANDARD DEVIATION	1ST QUARTILE	3RD QUARTILE	MIN	MAX
CO_2	**6.5**	**2.6**	**5.0**	**7.6**	**1.4**	**26.2**
CH_4	**19.5**	**5.0**	**16.1**	**21.6**	**9.4**	**63.8**
N_2O	**5.6**	**1.7**	**4.4**	**6.6**	**2.1**	**12.5**
GROSS GHG	**31.6**	**7.3**	**26.5**	**34.9**	**14.9**	**82.4**
CARBON SEQUESTRATION	**3.7**	**3.2**	**1.7**	**5.2**	**-9.0**	**29.6**
NET GHG	**27.9**	**7.1**	**23.4**	**31.3**	**-7.4**	**62.3**

Note: The negative values for carbon sequestration are due to several farms trapping carbon in the pastures and meadows instead of releasing it into the atmosphere because of tilled soils.

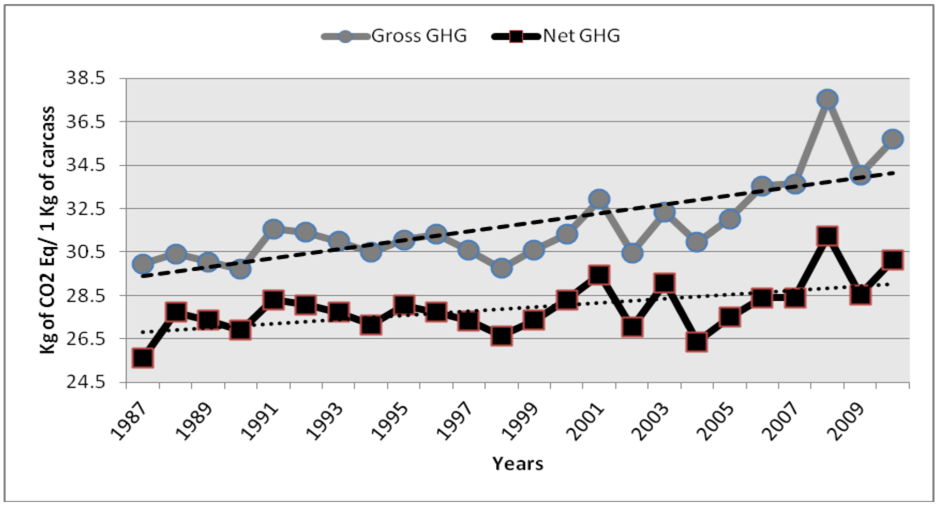
Table 2. Systems and emissions nature

Systems	**Gross emissions**		**Carbon Sequestration**		**Net emissions**		**Observations**
Conventional	31.6	^{a}F Stat=8.730	3.6	^{a}F Stat=5.430	28	^{a}F Stat=9.780	1089
Organic	30.8	^{b}Pr (>F)=0.000	4.8	^{b}Pr (>F)=0.004	26	^{b}Pr (>F) <0.0001	80
Montain	32.4	^{a}F Stat=13.070	5.3	^{a}F Stat=378.746	27.1	^{a}F Stat=15.709	601
Plain	30.9	^{b}Pr (>F)=0.000	2.1	^{b}Pr (>F) <0.0001	28.8	^{b}Pr (>F) <0.001	579

a refers to the Fischer statistics of the ANOVA analysis
b refers to the probability of incorrectly rejecting the null hypothesis of means equality
Note: In the sample we also have farms in conversion to organic system production, but we did not show their results because of the low number of observations.

To analyze the evolution of GHG emissions, average emissions of the total sample is declined by year. Figure 1 displays this evolution and shows upward trends, i.e. emissions increase over time. Among the factors that explain this situation is the decrease of production levels due the decline in the numerical productivity of about 18% from 1987 to 2010. We can also add the rise of the consumption of concentrate per ewe. Additionally, the higher levels of investment in machinery and breeding equipment also played a role in these observed trends. Gross and net emissions follow the same tendency. We recorded the highest emission levels in 2008. This can be explained, apart from the factors cited previously, by the apparition of a sheep disease (Bluetongue) which reduces ewe productivity. Since the Functional Unit is based on the carcass weight the relative level of GHG emissions increases.

Figure 1. Gross and Net GHG emissions over years.



Note : The sample in this analysis is not constant; therefore, for the sake of comparison between years, we generate bootstrap samples for each year and compare the results to the non-bootstrap ones. We found no differences between these results and decided not to show the bootstrap results.

3. CONCLUSION This work implemented a LCA on a sample of French sheep farms and concluded that the production of one Kg of carcass corresponds to the emission of about 32 Kg of CO_2 equivalents. The evolution analysis showed an increase in GHG emissions. It would be quite interesting to carry on with this work to explain the reason for the observed evolution, and to complete the study with an economic approach by looking at the correlation between these emissions and the farms' economic performances.

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