Ex-post evaluation of GHG emissions and energy consumption in organic and conventional meat SHEEP farms in France over 26 years

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Abstract

This study aims at comparing GHG emissions and non-renewable energy use in meat sheep production, in organic farming (OF) and conventional farming systems. These two criteria have been calculated ex-post on 1261 French year-farms monitored over 26 years. The functional unit used is the carcass weight. Regarding GHG emissions, the results show that OF emit 5 % less GHG than conventional ones, with a higher proportion of methane and less indirect CO_2 associated to less inputs use. Given the methodological difficulties, it is hard to argue if carbon sequestration in soil is different between OF and conventional. For non-renewable energy, there is no significant difference between OF and conventional farms, due to compensations (more mechanization and less concentrates and fertilizer purchased in OF). Note the great variability in the results, both in OF and conventional farms. The two main explanatory factors are ewe productivity (for GHG) and forage self-sufficiency (energy consumption).

Introduction

Livestock farming environmental impact, particularly in terms of global warming has been considered as a major issue among many international institutions. Besides, depletion of non-renewable resources, including energy, requires accounting for the non-renewable energy consumption in farms evaluation criteria. However, these issues also matter in organic farming, which of course has a very positive impact on the environment due to the non-use of pesticides and fertilizers, but it is not possible to answer a priori positively or negatively to this assertion. In fact GHG emissions and energy consumption depend on both structural and technical factors, and the level of use of different inputs. Based on a network of French meat sheep farms monitored on the long run, we compare the performance of organic vs. conventional farms in terms of GHG emissions and energy consumption. Moreover, the analysis also addresses the question of the identification of specific factors that have large influences and could be used to improve these balances.

Material and methods

This work is based on a sample of 1261 farms-years surveyed from 1987 to 2012 in the center of France. It is a non-constant sample due to some entrances and exits of farms each year but it is kept stable as much as possible from year to year. The farms are located in mountain and piedmont areas (North Massif Central) with the use of hardy breeds, and in lowland low agronomic potential areas (North and North West of the Massif Central), with grassland breeds. Of these farms-years, 88 are involved in organic farming production but there number is largely concentrate in the second part of the period (from 1999). These farms were firstly investigated in order to identify factors explaining their economic performances. Many variables, about farms structure, production types and field patterns (grasslands, crops), mechanization and buildings characteristics, and other farms inputs (concentrates, fertilizers, and so forth), were recorded during the surveys. Yet, these investigations were not initially intended for environmental impacts' appraisal and thereby an intense methodological work was needed to overcome some missing information. Recently, two years of finer surveys (2011 and 2012) were used to build some relationships between economic data and missing quantitative information for the environmental impact assessment. For example, regression technics were used to fit an expressive relation between monetary values and environmental variables (GHG emissions and energy consumption) for the case of farm machinery, buildings and pesticides use. The estimated equations were then use for the previous years after adjusting for prices changes on the basis of an appropriate statistical series.
The balance of GHG emissions and non-renewable energy consumption has been made according to the Life Cycle Assessment (LCA) methodology. For the evaluation, we took advantage of the Dia'Terre tool developed by ADEME (French Environment and Energy Management Agency) and which in turn is largely based on GES'TIM (from French Livestock Institute). Dia'Terre is the result of a national consensus (France) aiming to conduct large-scale surveys of the entire French agriculture. In the GHG calculation, carbon

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sequestration was also accounted for, following the work of Arrouays et al. (2002). The Functional Unit (FU) is defined as the kilogram of carcass weight. Some allocation issues were also raised during the computations between meat and wool. Finally we made a mass allocation between these two products, for energy and GHG.

Results

The average total emission level of all farms is 37.2 kg of CO_2eq/kg carcass. After a mass allocation between meat and wool this level falls at 32.7 kg of CO_2eq/kg carcass because wool weighs approximately a little more than 12.1 % of the total mass of the unit's products. The average level of carbon sequestration in soils (difference between the storage of grasslands and the destocking related to the tillage of crops or grasslands areas) is around 4 kg of CO_2eq/kg carcass i.e., 12 % of the gross emissions. Methane (CH_4) is by far the most significant gas and represents about 61 % of the total emissions. It is followed by carbon dioxide (CO_2) and nitrous oxide (N_2O) which, respectively account for 21 % and 18 %. Enteric fermentation is the major source of methane emissions (78 %). CO_2 emissions derived mainly from animal feedstuffs purchase (35 %), fertilizers (20 %) and fuels (19 %). The N_2O emissions are firstly due to manure management in housing and pastures (58 %), then runoff and leaching (24 %), and the use of mineral nitrogen fertilizers (17 %). Gross emissions are lower on average by 5 % in organic farms. This difference is rather small but it is statistically significant (Wilcoxon non parametric test). In fact, the share of CH_4 is slightly higher for organic farms (68 % vs. 60 % in conventional farms) while the proportions of CO_2 and N_20 are smaller, in line with the lower level of inputs use.
About energy consumption, it is on average around 79.8 MJ/kg carcass. In proportion three inputs are comparable: fertilizers (25 %), animal feedstuffs (24 %) and, fuels and lubricants (23 %). Farm machinery accounts for about 8 %, electricity 4 % and buildings 3 %. There is no significant difference for the total amount of energy consumption between the two production systems (organic and conventional). In fact the lower level of some inputs like fertilizers (13 % against 26 % in conventional) and feeds (21 % vs. 24 %) in organic farming is compensated by a higher consumption of fuels (29 % vs. 22 %) and machinery (12 % against 8 %).

Discussion

A few studies using the LCA methodology have assessed the environmental impact in meat sheep farms (Table 1). Gross GHG emissions are low when ewe productivity is rather high and farming system based on grass, as in New Zealand. On the other side, emissions are higher when lamb weight is very low (Spain). However, the comparison might be biased because of the differences in the methodology adopted by authors, system boundaries, emission factors, functional unit and allocation issues. It also appears that other papers don't include organic farming systems in their analysis. A sensitivity analysis made on our sample of farms shows that the first factor explaining the GHG emissions is the ewe productivity (number of weaned lamb produced per ewe and per year). But the relationship is not linear: there is a threshold of 1.35 beyond which the gain in GHG reduction marginally decreases given the high level of inputs necessary to ensure high ewe productivity. Farms involved in organic farming have an average ewe productivity of 1.28 against 1.36 in conventional farms. Actually, high productive systems (three lambings in two years) are not affordable in organic systems (Benoit et al., 2009).The high importance of ewe productivity for low GHG emissions per kg carcass is directly related to the high contribution of enteric CH_4 in the total emissions. In fact, in this work the enteric methane was based on IPCC Tiers 2 method with a level of 11 Kg CH_4 per ewe and per year (Vermorel et al., 2008). This standard level was used as we were unable to rebuild all animal rations for each season and physiological stage of animals. Moreover, the quality of stored and grazed forages is not. However, for lambs we took into account their average duration of fattening and the average amount of concentrates used.

Table 1: Gross GHG emissions in some countries. GHG emissions per kg carcass or body weight is sometimes approximated with average 0.45 of carcass yield (Cf approx.).

Studies	Country	Per body weight	Per carcass weight
Dakpo et al., current study	France	14.7 (approx.)	32.7
Edwards-Jones et al. (2009)	Wales	12.9	28.7 (approx.)
Casey and Holden (2005)	Ireland	10.0	22.2 (approx.)
Williams et al. (2008)	UK	14.1	31.3 (approx.)
Ledgard (2010)	New Zealand	8.6	19.1 (approx.)
Ripoll-Bosch et al. (2013)	Spain	19.5 to 25.9	39.0 to 51.7

In terms of carbon sequestration, against all odds, conventional farms apparently sink more (by 25 %). This can be explained by the search of food self-sufficiency in organic farms (84.2 % vs. 83.1 % in conventional) which leads to the implementation of more crops areas, and therefore more plowed surfaces. We can consider there is a methodological problem because conventional farms use more purchased concentrates, grown in other farms. Assuming on one hand that the external crop surfaces for these concentrates destock one ton of CO_2eq per hectare and per year, and in the other hand that destocking is not possible beyond some threshold (for instance like in crops systems, destocking is note possible on the very long term), then the two type of systems show similar carbon sequestration's rate. One more point is that when applying the coefficient suggested by the JRC (Leip et al., 2010), the results are completely different. All this is showing that the issue of carbon sequestration issue is very sensitive.

We know that organic standards and principles lead organic farms to use less inputs especially fertilizers and concentrates feeds. But these gains (in terms of energy) are systematically cancelled due firstly to their lower ewe productivity and secondly to the higher levels of fuel consumption and machinery use per unit produced. In fact, the seeking of feed self-sufficiency lead these farms in the production of more on-farm concentrates which requires more fuels consumption and certainly more investment in farm equipment per unit produced.

Conclusion

As a conclusion, we found little difference in GHG emissions and energy consumption between organic and conventional production. However, there is a high variability within and between each farming system. The analysis also pointed out two major factors explaining the levels of environmental impact: animal productivity and fodder and feed self-sufficiency. It has already been proven that these factors are also determinants in the economic performance (Benoit and Laignel, 2011). Besides, it is important to remember that these LCA methodologies are complex (equations, adapted standards) and significant methodological developments are expected (especially for carbon sequestration). It is also important to keep in mind that ruminants have the unique ability to produce high-quality protein from fodder. And enteric CH_4 as a crucial determinant of this environmental assessment is intrinsically linked to this ruminants' ability. In addition, it appears that sheep farming activities help in maintaining harsh natural habitats and this environmental service should also be accounted for. Finally, in this comparison, we have not addressed all the environmental impacts and especially the major advantage of organic farms in pesticides use.

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