Organic Farming and Climate Change
Can organic farming mitigate the impact of agriculture on global warming?

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ABSTRACT

Agriculture is responsible for more than 30% of the total human-induced greenhouse gases (GHG) emissions. Three gases are responsible for those emissions: CO_2, CH_4 (methane) and N_2O (nitrous oxide). Organic farming emits less GHG than conventional farming for several reasons: lesser energy use, lesser nitrogen use, no artificial fertilizers, more grassland, sequestration of carbon in the soil. However, the ability of organic farming to mitigate the GHG emissions is strongly dependant on the way it is practiced. Our food habits, and mainly the part of animal food (specially ruminant meat) have also a strong influence on the GHG emissions of food.

1. Introduction

Global warming represents a major threat for food security, especially in tropical countries. It is expected that global warming will worsen the drought and the irregularity of rainfall in many countries. Mitigating the emissions of greenhouse gases is therefore an important challenge that can significantly contribute to improve food security. This can be achieved by reducing the CO_2 emissions due to combustion of fossil fuels, but also by changing agricultural techniques and food habits.

Agriculture is responsible for at least 30% of the global warming (Table 1). This important contribution is due to three gases: CO_2 (carbon dioxide), CH_4 (methane) and N_2O (nitrous oxide).

- CO_2 emissions come mainly from the fertilizers industry, from the machinery used on the farm and, according to the production system and to the changes in land use, from the release in the air of part of the carbon present in the soil. Deforestation is also an important contributor to the emissions of CO_2 by agriculture.
- CH_4 emissions come mainly from livestock, from enteric fermentation of ruminants and manure fermentation, and also from rice fields.
- N_2O emissions come mainly from the soil (nitrification and denitrification) and to a lesser extent from animal manure.

Table 1: Greenhouse Gas emissions by agriculture (after Scherr, 2008)

Emission sources	Annual emissions (million t CO_2-eq)	Gas emitted
Soil fertilization (organic and mineral)	2,100	Nitrous oxide
Entric fermentation in rumen	1,880	Methane
Biomass burning	700	Methane, nitrous oxide
Rice production	600	Methane
Livestock manure	400	Methane, nitrous oxide
Other (mechanization, irrigation, greenhouses)	900	Carbon dioxide, nitrous oxide
Deforestation and devegetation	8,500	Carbon dioxide
Total	15,080	
Fossil fuel burning (for comparison)	27,700	Carbon dioxide

The impact of organic agriculture, compared to conventional agriculture, has not been very extensively studied. However, some conclusions can be drawn from research done in this field, in particular on the factors influencing the emissions of greenhouse gases by agriculture.

2. Energy consumption and carbon dioxide (CO_2) emissions

The direct energy consumption (mainly for mechanization) is about the same in organic and conventional agriculture. But if we add the indirect consumption, mainly for the manufacture of nitrogen fertilizers, the total energy consumption becomes much lower in organic agriculture, at least by hectare. Indeed the production of 1 ton of N as chemical fertilizer needs about 1 ton of oil and even more in some factories.

In Great Britain, a research made by the Ministry of agriculture concluded that, for most of the productions, the amount of energy used to produce 1kg of food is lower in organic than in conventional agriculture: for example, it amounts, for vegetables, between 28 and 75% of the energy used in conventional agriculture, for beef 55%, for wheat 84%. On the contrary, the organic production uses 14% more energy per kg than the conventional for potato, 10% more for eggs, 11% more for chicken (Figures 1, 2 and 3).

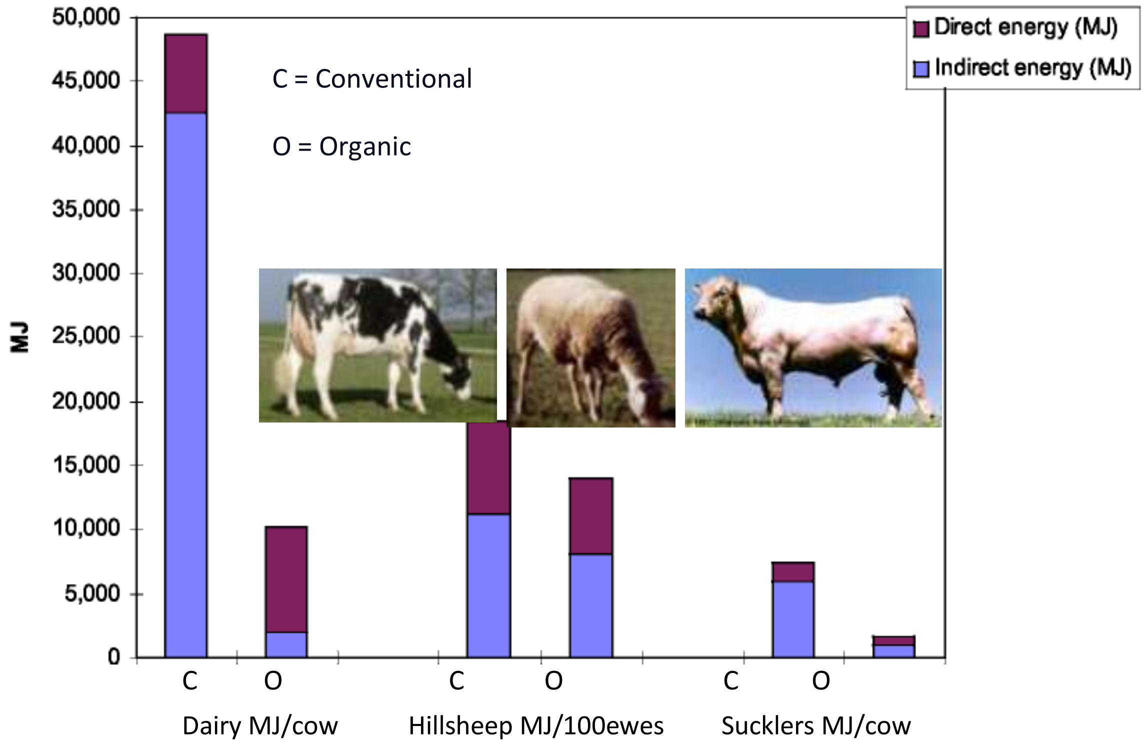

Figure 1 - Direct and indirect energy consumption in different types of stock breeding (after MAFF, 2000)

In France, according to the results of 950 farms, 274 of which being organic, the energy consumption par ha is much lower in organic farms for all types of production, but with a great heterogeneity. For instance in grain production the energy consumption is 66% higher in conventional because the fertilisation represents 46% of this consumption, whereas it is only 6% in organic. By ton of product, the result is better in conventional farms for productions, like grain, where the differences in yield are important. For other productions, for instance milk, the organic remains more efficient by litre of milk produced (Bochu, 2008).

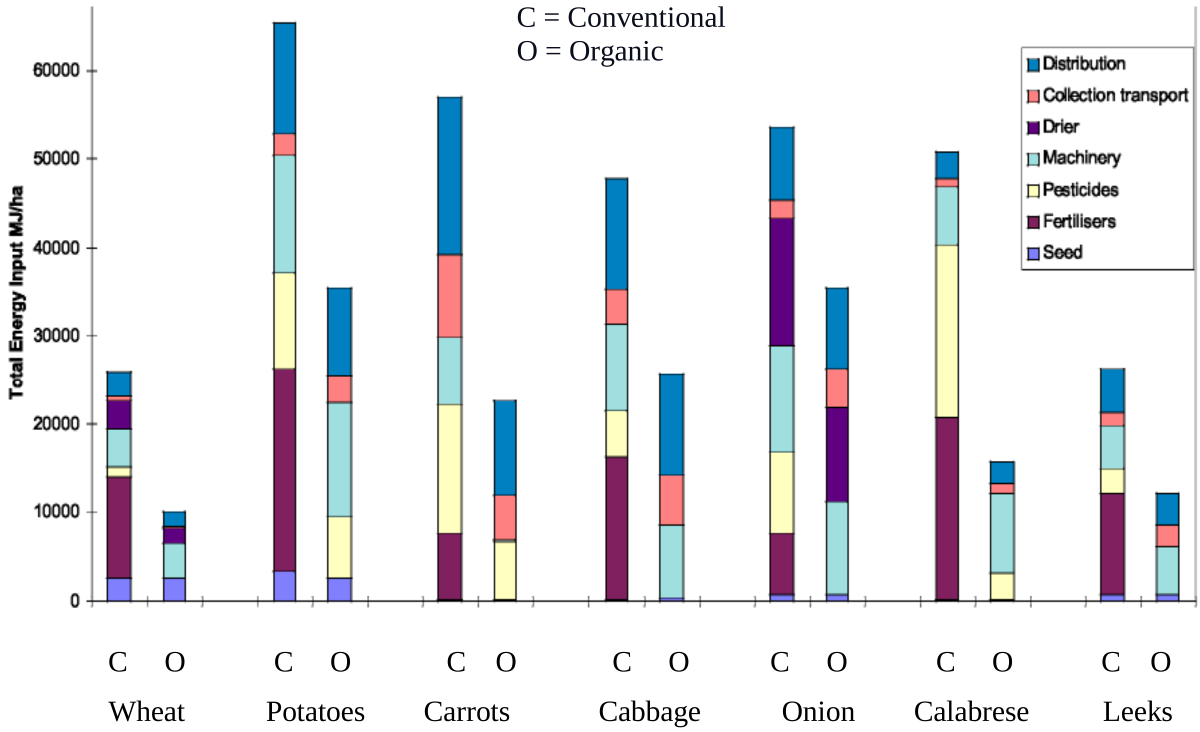

Figure 2: Energy consumption per area unit in organic and conventional agriculture (MJ/ha) (after MAFF, 2000)

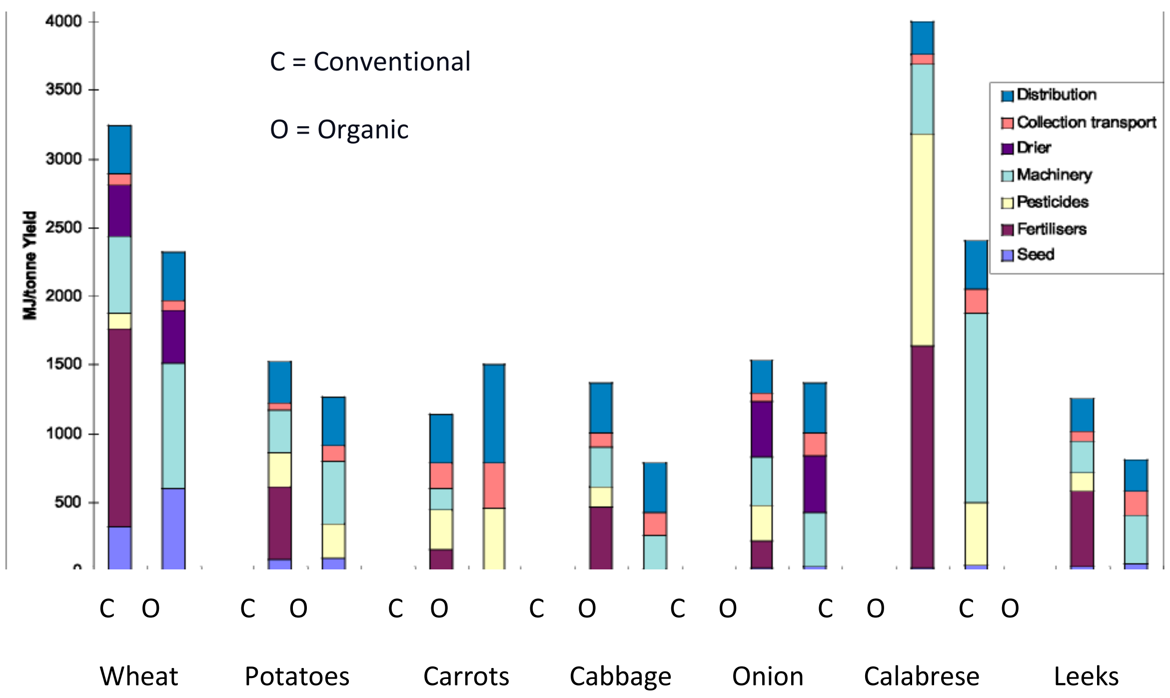

Figure 3: Energy consumption per ton in organic and conventional agriculture (MJ/ton) (after MAFF, 2000)

In Germany, a comparison between 18 organic and 10 conventional farms showed that the energy input per ha is always lower in organic than in conventional farms (Figure 4).

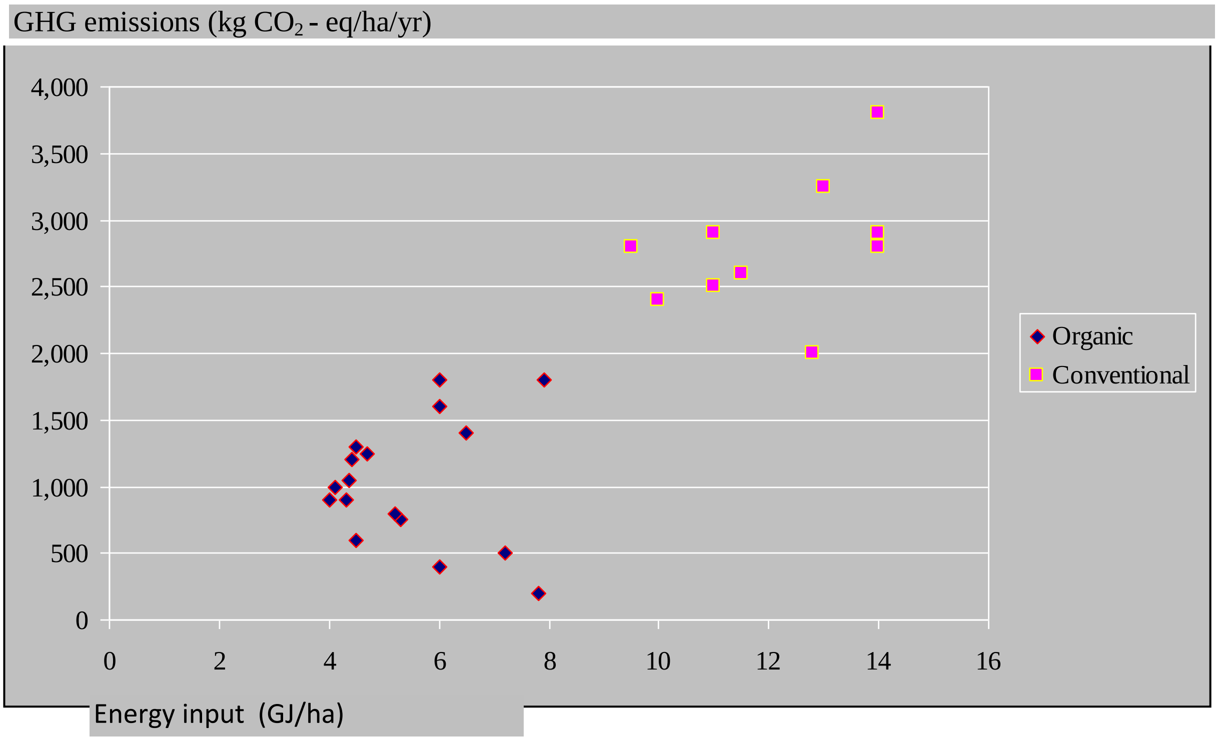

Figure 4 - Greenhouse gases emissions according to energy input (Hülsbergen, 2008)

3. Methane (CH_4) emissions

The methane emissions are not much lower in organic than in conventional agriculture. However, the longevity of milking cows – which is usually longer in organic than in conventional stock breeding - is a way to decrease the amount of methane produced per kg milk (Figure 5).

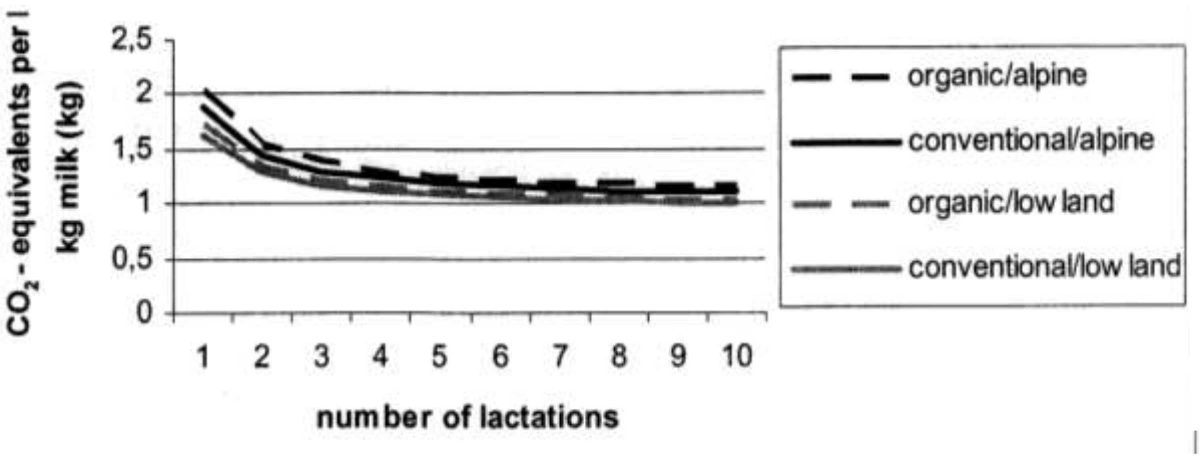

Figure 5: GHG emissions by litre milk according to the production system and the number of lactations (Boincean, 2008).

As far as the fermentation of effluents is concerned, the reduction of GHG emissions by composting has been confirmed by several experiments, the emissions of methane being much lower and not offset by the slight increase in N_2O emissions. For exemple, in an experiment in Canada the GHG emissions have been 487 kg eqCO_2/cow/year by composting, 729 kg with manure heap and 1481 with slurry (Pattey, 2008).

4. Nitrous oxide (N_2O) emissions

N_2O is emitted mainly by the soils. The amount emitted per ha and per year depends on many factors : type of soil, type of crop, rainfall, rotation, compaction of the soil, amount and type of nitrogen fertilization. The main factor related to the farming techniques is the nitrogen fertilization. The N_2O emissions increase rapidly with the amount of nitrogen fertilizers (Figure 6).

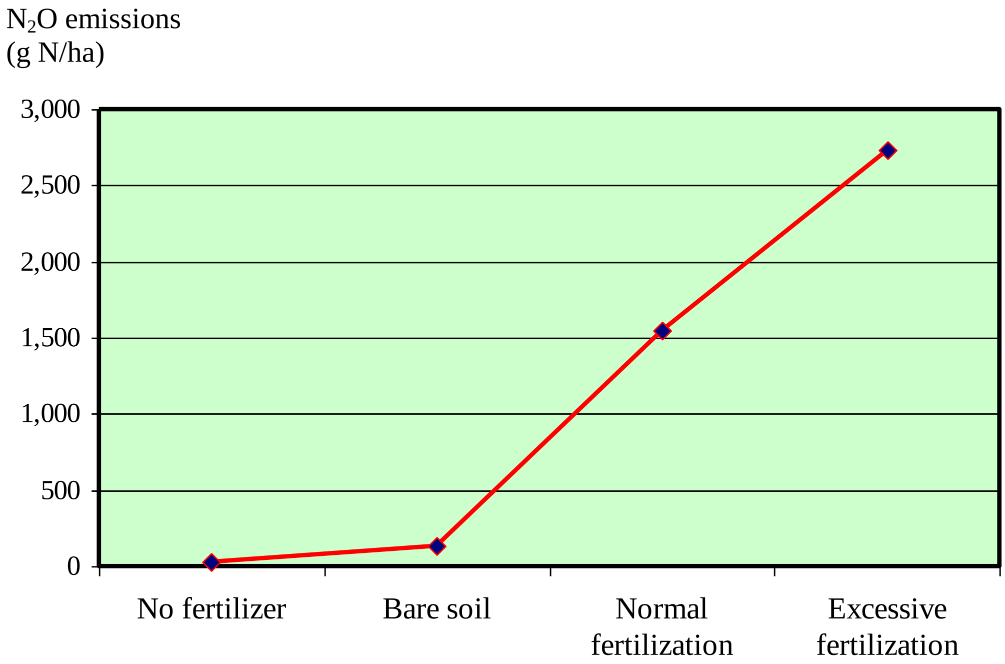

Figure 6: N_2O emissions according to the fertilization (rape production) (Germon, 1999)

Nitrogen fixed by legumes contributes considerably less to N_2O emissions than nitrogen spread as fertilizer. This leads to revise the evaluations based on the default IPCC emission factor (1% of nitrogen applied), which was the same for nitrogen fertilizers and for symbiotic fixation. Consequently, on a farm, the more nitrogen fixed biologically, the less N_2O is emitted.

Table 2: Greenhouse gas emissions per ton chemical nitrogen (kg CO_2- eq/ kg N) (author's estimation)

Energy consumption by manufacture	2.7
N_2O emissions by manufacture	4
Indirect N_2O emissions by application	4.9
Indirect applications by application	4.1
Total	15.7

Table 3: N_2O emissions by nitrogen fertilisation (kg CO_2- eq/ kg N) (author's estimation)

Chemical nitrogen	15.7
Organic nitrogen	9.0
Biologicaly fixed nitrogen	1.0 - 2.0
Total	25.7 - 26.7

In a research made in Denmark (Olesen, 2008), the impact of various factors (rotation, fertilization, green manure) has been studied. The emissions are lower in organic systems and are decreased with green manuring and increased with manure application. In this experiment, the emissions per kg produced are higher in organic systems if the IPCC default emission factor is applied. If the emissions due to the nitrogen biologically fixed are considered as not higher than the background emissions, which is a better estimation, the emissions remain superior in organic in the rotation without annual legumes, but lower in the rotation with legumes.

The N_2O emissions are closely related to the nitrate (NO_3) content in the soil. As shown in Figure 7, the nitrate content in the soil is in most cases much lower in organic than in conventional soils.

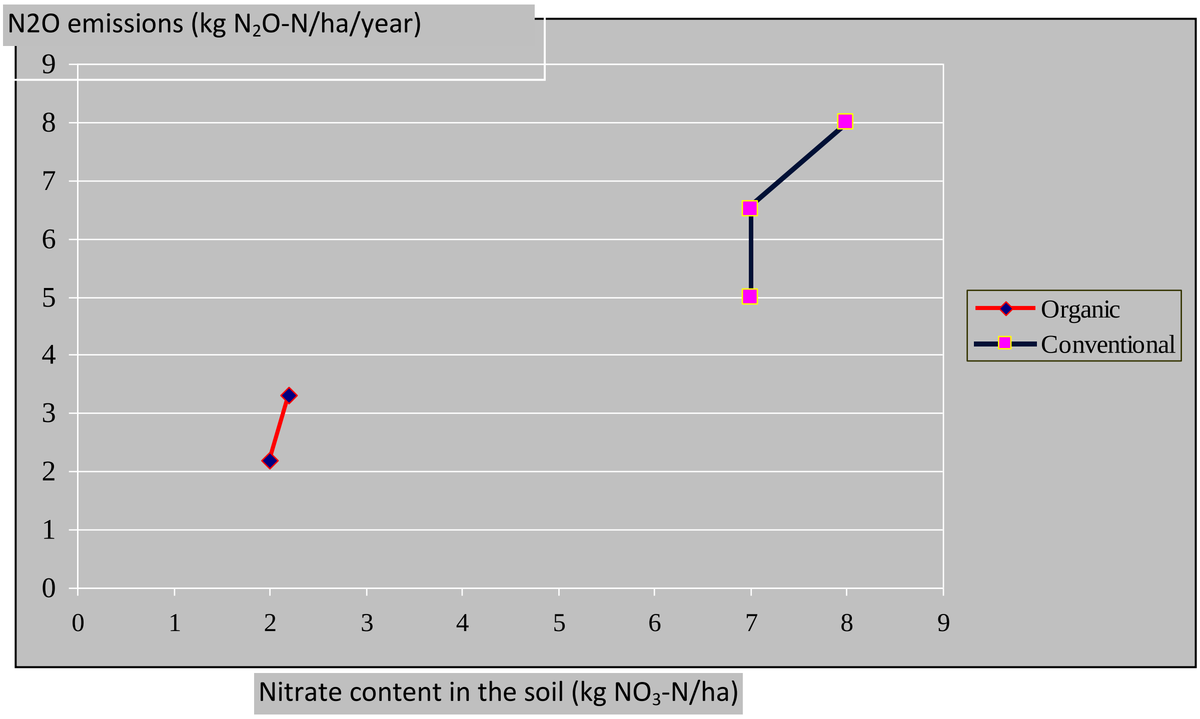

Figure 7: N_2O emissions according to the nitrate content in the soil (Sehy, 2004)

5. Global Warming Potential (GWP): CO_2 + CH_4 + N_2O emissions

The results of two long term comparisons between organic and conventional systems in Switzerland (DOC and Burgrain experiments) show that the emissions per ha and per kg produced are lower in organic systems (Figure 8).

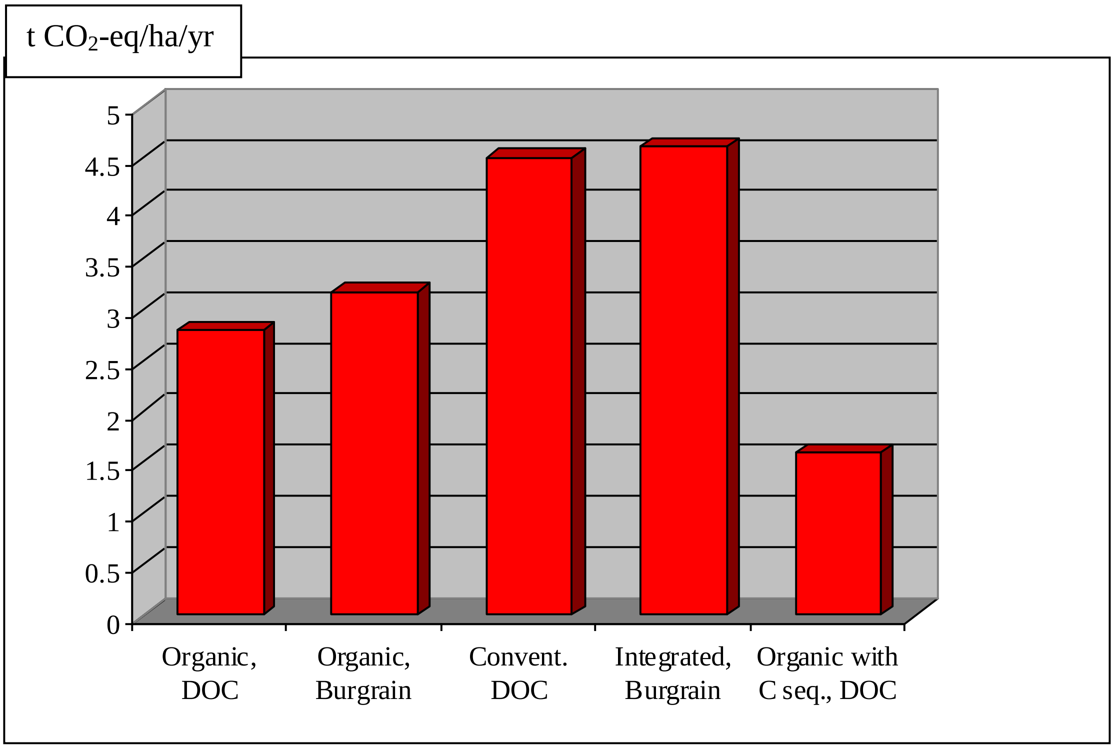

Figure 8 - GHG emissions in organic and conventional agriculture (after Nemececk, 2008)

6. Sequestration of carbon in the soil

The data are variable according to the situation and the production system. The amount sequestered in organic farming varies, in most cases, between about 100 kg C/ha/year and more than 500 kg C/ha/year (Table 4).

In stockless farms, in some cases, organic agriculture can de-sequester carbon (Brock, 2008),

An experiment made in Moldavia has confirmed the importance of having perennial legumes in the rotation: in two rotations with manure supply, the one with legumes increased the organic matter content of the soil, whereas the one without legumes decreased it. On the other hand, the variant with manure + NPK did sequester more carbon than the variant with only manure (Boincean, 2008).

Comparisons between different experiments are sometimes difficult because the depth at which the samples have been taken is not always made clear, and the amount of organic present in the top soil may be only half, or even less in tropical regions, of the total amount.

In comparisons with conventional agriculture, the results are different if one considers the net amount sequestered in the soil or the difference with conventional agriculture (Table 5). For instance, in the DOC experiment (Fibl, Switzerland) the amount sequestered in the biodynamic plot was only + 87kg C/ha/year, but the difference with the conventional plot was + 287 kg C/ha/year.

In order to compare the capacity of organic agriculture to sequester carbon, the comparison should be done at the regional scale taking in account the change in soil utilization (from annual crops to grassland or the contrary), the plantation of hedges, etc. In Great Britain, for instance, 13 millions of carbon from the soil are lost every year, which represents 7.3% of all GHG emissions in this country (Aseez, 2008)

Table 4: Gain in carbon in the soil in organic compared to conventional agriculture

Type of experiment	Country	Gain in carbon in the soil in organic compared to conventional agriculture (kg C/ha/yr)	Author and year of publication
DOC (Fibl, Suisse)	Switzerland	287	Fliessbach, 2008
Long term trial Rodale Institute	USA	688	Hepedy, 20008
Comparative study of 18 organic and 10 conventional farms	Germany	170	Hulsbergen, 2008

The average gain is 380kg C/ha/year, in accordance with estimations made by other authors.

Table 5: Impact of various agricultural practices on carbon content of the soil (t C/ha/year) (Source : Hülsenbergen, 2008)

Change of land use from pasture to cropland	> -1
Maize for silage	- 0.4 to - 0.8
No till	0 to + 0,25
Fertilization with manure or compost	> +0,5
Organic agriculture	0 to + 0,5
Perennial legumes	+0,6 to >1
Change of land use from cropland to pasture	> 1

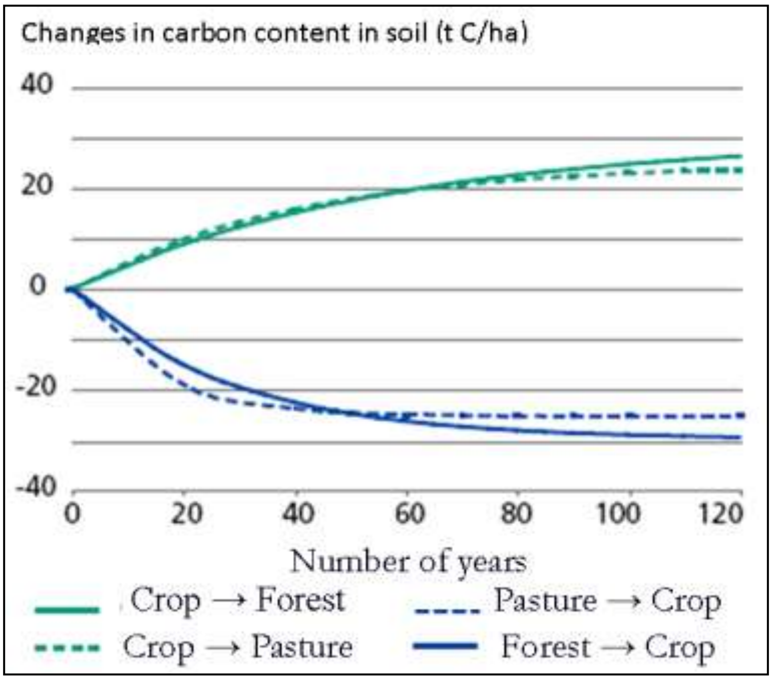

Figure 9: Changes in carbon content in the soil according to land use change (author)

Farmers' aiming at the mitigation of the GHG emissions by organic (and conventional) agriculture should include following practices:

- Replace, as far as possible, nitrogen fertilizers (organic and mineral) by more legumes
- Feed the ruminants more grass and less maize grain, grain and soya cake
- Improve the rotations (more legumes, especially perennial, more green manure)
- Compost animal dejection
- Produce biogas.

7. Impact of food habits

The food habits have an enormous impact on the GHG emissions by the production of food.
The part of animal products and particularly of meat but also of milk, in the diet has a very high impact on the contribution of our diet on the GHG emissions. For example, the production of 1 ton milk emits about 1 ton CO_2- eq, whereas 1 ton of soymilk emits 10 times less (Riedecker, 2008). But the highest impact is the consumption of the meat of ruminants: the production of 1 ton protein as ruminant meat emits about 30 times more GHG than as legumes.

The food industry emits also a lot of GHG: the production of 1kg deep frozen French fries emit 5.7 kg CO2eq (Redlingsdhofer, 2008).

Decrease the meat consumption would strongly contribute to mitigate the GHG emissions from food (Figures 10 and 11).

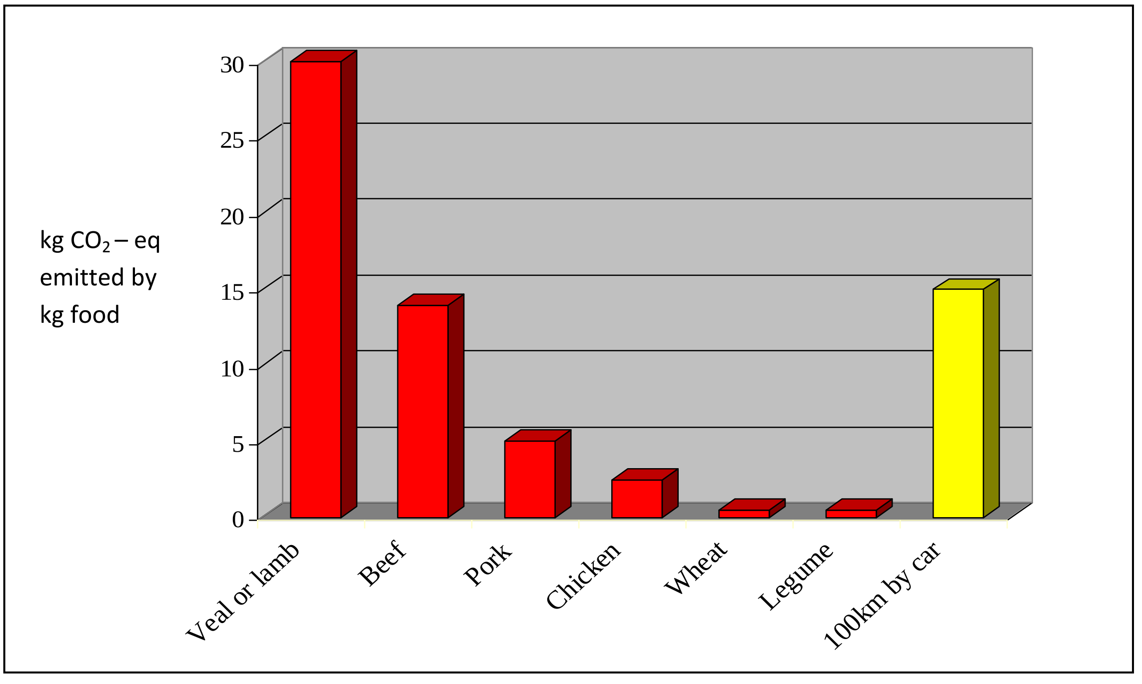

Figure 10: GHG content of vegetable and animal food (Aubert C, 2007)

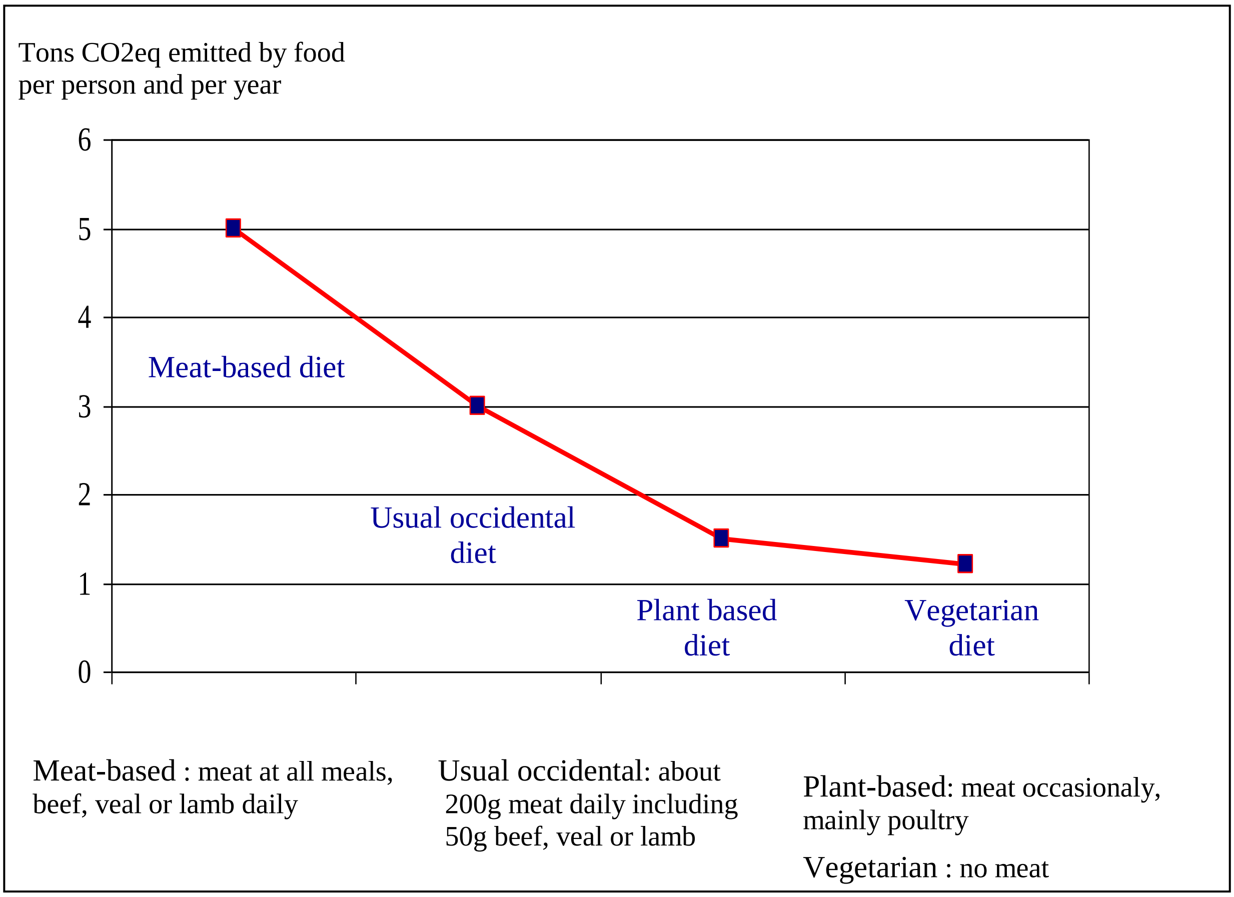

Figure 11: Amount of CO_2-eq in our plate according to our food habits (Aubert, 2008)

8. Conclusion

Based on the on the above presented evidences the following conclusions can be made in regard to organic farming and GHG emissions:

1. Organic agriculture emits less GHG than conventional agriculture.
2. Organic agriculture can still improve its mitigation potential (with better rotations, more legumes, energy savings, renewable energies).
3. Changing our food habits (eating organic, less animal food, eat local, etc.) can strongly reduce the GHG emissions of our food.
4. Divide by two, or more, the GHG emissions of agriculture and food is possible but it needs political and individual will to change agriculture techniques and food habits.

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