# The variability of the greenhouse gas emissions in winter oilseed rape produced in France

Francis Flénet [(1)]
[(1)] CETIOM, Avenue Lucien Brétignières, 78850 Thiverval-Grignon, FRANCE. flenet@cetiom.fr

The European Union decided to promote biofuels in order to decrease the emissions of greenhouse gas (GHG) and the importation of non renewable energy (Directive 2003/30/EC). The biofuels used in Europe must fulfil sustainability criteria, among with there is a minimum saving in GHG compared with the non-renewable fuel (Directive 2009/28/EC). The minimum saving value will be 35% until 2016, and then it will be increased to 50%. Hence, the GHG emissions of crops which produce the raw materials for biofuels are key issues.

In France, rapeseed biodiesel is the main biofuel. According to the Life Cycle Assessment of the first generation biofuels produced in France (BIO IS, 2010), the GHG saving of rapeseed biodiesel is 59%, the cultivation of oilseed rape accounts for more than 75% of the total emissions, and the main GHG is the $N_2O$ emitted by soils. However, in this study the effect of indirect Land Use Change (iLUC) was not taken into account. Moreover, the GHG emissions will be calculated each year for each grain storage company. Hence, "low GHG" crop managements will probably be necessary in order to achieve the 50% saving criteria each year in each region, especially if an iLUC emission value is taken into account.

The first objective of the study was to evaluate the possibility to achieve the 50% GHG saving criteria each year in each of the main French regions producing oilseed rape. The second objective was to study the possibility to reduce the GHG emissions by improving the efficiency of mineral N fertilization or by applying organic matter (OM).

**Material and methods**

The GHG saving value of rapeseed biodiesel (GHG_S) was calculated from the estimation of the emissions of this biofuel (GHG_B) and from the emissions of fossil diesel which is 83.8 g $CO_2$ eq $MJ^{-1}$ (European Directive 2009/28/EC) : GHG_S (%) = 100 · (83.8 – GHG_B) / 83.8. In order to estimate the GHG emissions of cultivation, 27 grain storage companies (GSC), located in the main French regions producing oilseed rape, were surveyed in 2010: the seed yields and the cultural practices of about 5000 oilseed rape fields were recorded. From these results, the emissions due to diesel consumption and due to the fabrication and transportation of pesticides and mineral fertilizers (NPK) were calculated. The $N_2O$ emissions by soils were also estimated, using the Tier 1 method of IPCC (De Klein et al., 2006). The emissions of the processing of biodiesel and of the transports were set to the mean values for France (BIO IS, 2010). No other emissions were taken into account (i.e. carbon stock changes caused by iLUC, soil carbon accumulation via improved agricultural management…). The GHG emissions were allocated between the main product (biodiesel) and the co-products according to their energy content, as it is recommended in the European Directive 2009/28/EC.

In order to study the year effect on seed yield, the statistics of the 5 past years were taken into account (2006-2010). During this period, the French mean oilseed rape yield ranged from 2.90 to 3.78 t $ha^{-1}$, and the 2010 yield (3.27 t $ha^{-1}$) was quite a medium value: the highest and the lowest mean yields were respectively 1.16 and 0.89 as great as that observed in 2010. Hence, the GHG emissions with 85% and 115% of the seed yields recorded in 2010 in each grain storage company (GSC) were calculated. The improvement of N fertilizer efficiency could be obtained from an extended use of calculation tools, because almost 50% of the French farmers do not use any (CETIOM survey). Moreover, some Farmers who use a tool apply a higher amount of N fertilizer than the calculated value. Hence, the GHG emissions were calculated with 30 kg N $ha^{-1}$ less mineral fertilizer without any effect on seed yield. The application of 50 kg of organic N $ha^{-1}$ was also studied, because this amount could be applied before sowing with little risk of increasing nitrate leakage. Two hypotheses were tested: the fertilizer efficiency of organic N was the same as that of mineral N or 50% lower, resulting in a decrease in mineral N fertilizer of 50 or 25 kg N $ha^{-1}$ respectively.

**Results and discussion**

The GHG emissions of biodiesel ranged from 30-32 to 42-44 g eq. $CO_2$ $MJ^{-1}$ (Figure 1), depending on the GSC collecting the rapeseed. Hence, in 2010 the 50% GHG saving criteria was achieved for all GSC except one. However, the number of GSC failing to fulfil this sustainable criteria would be greater if the iLUC effect was taken into account. The variability of GHG emissions between GSC was mainly explained by differences in N application and in seed yield, the lowest GHG emissions being obtained with high rapeseed yield (3.7 t $ha^{-1}$) and low N applications (101 kg of mineral N $ha^{-1}$ plus 64 kg of organic N $ha^{-1}$) compared with other GSC (data not shown).

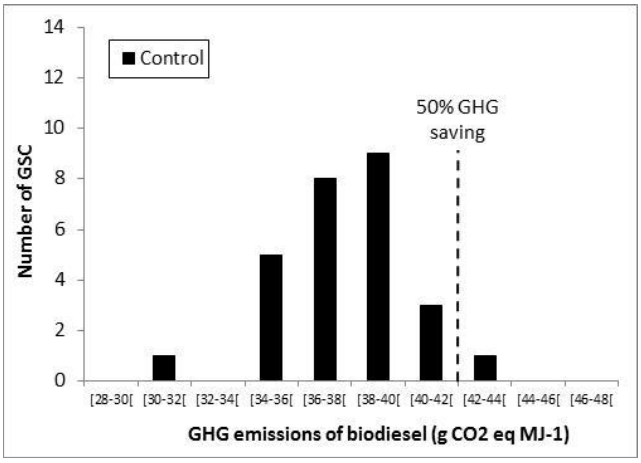



Figure 1 – Variability of the GHG emissions of biodiesel between grain storage companies

A major year effect was observed, because in the low yielding year (85% yield) the GHG saving was lower than 50% in half of the GSC (Figure 2a), while the lowest GHG saving was above 54% in the high yielding year (115% yield) (Figure 2b). These results show that ways of decreasing the emissions must be found in order to achieve the 50% GHG saving criteria each year in each location.

A 30 kg N $ha^{-1}$ decrease in the amount of mineral fertilizer had an effect on GHG emissions similar to a 15% increase in seed yield (Figure 3). Such an improvement in the efficiency of N fertilization would make possible the achievement of the 50% GHG saving criteria for each GSC in each year.

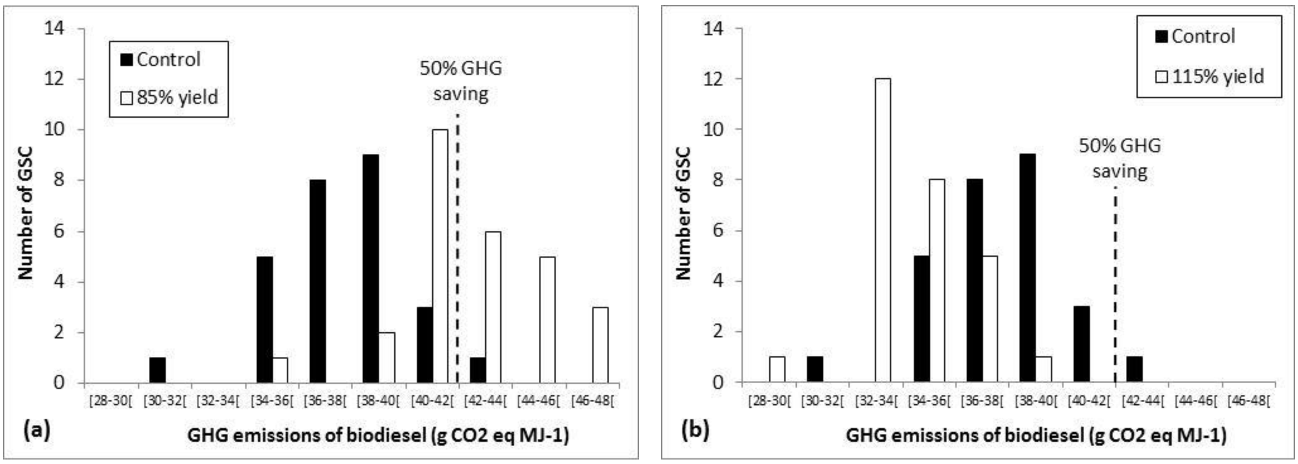



Figure 2 – Effect of oilseed rape yield on GHG emissions of biodiesel

The emissions calculated with the actual seed yields (control) were compared to those of fields yielding 15% less ((a), 85% yield) or 15% more ((b), 115% yield).

In France, a 10 kg N $ha^{-1}$ decrease in the application of mineral fertilizer was observed from 1996 to 2005 (Reau, 2006) due to the development of a calculation tool that takes into account the N already uptaken before the application of fertilizer. However, improvements are still possible because almost 50% of the French farmers do not use such a tool, and because some of those using a calculation tool apply a greater quantity than the calculated value. The obligation to reduce the GHG emissions of oilseed rape in order to sale the seeds for biodiesel should result in further acceptation and in better use of the N fertilizer calculation tools.

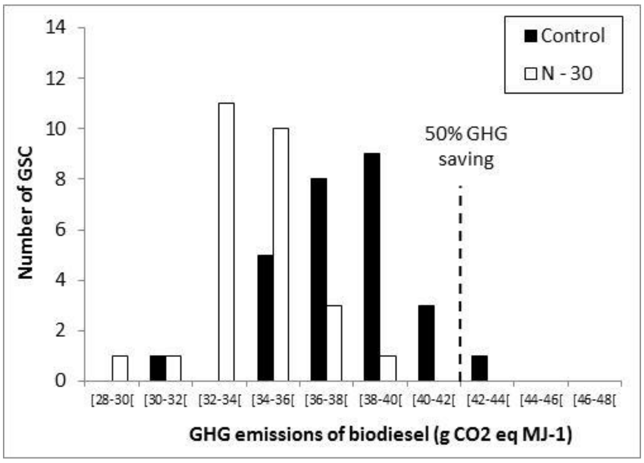
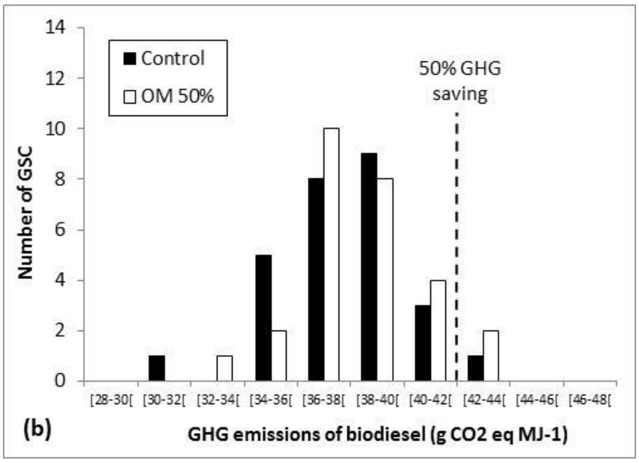



Figure 3 – Effect of the amount of mineral N fertilizer applied on oilseed rape crop on GHG emissions of biodiesel

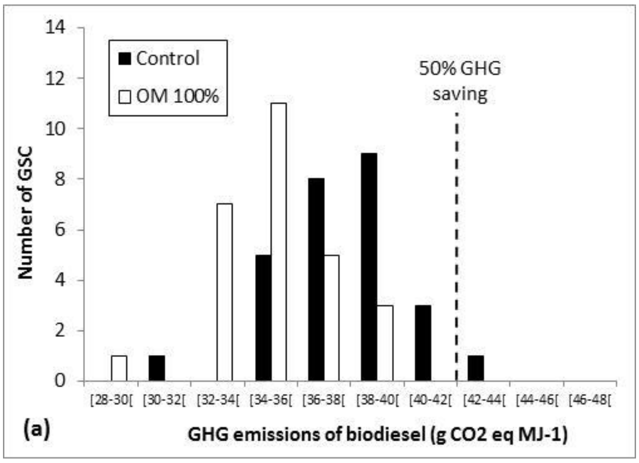
The emissions calculated with the actual amounts of N (control) were compared to those of fields receiving 30 kgN $ha^{-1}$ less (N – 30).

The application of OM may also be a way of reducing the GHG emissions of oilseed rape, because the production of mineral N fertilizer results in high $CO_2$ emissions due to the use of fossil energy. Moreover, the production of fertilizers containing nitrate also emits $N_2O$. However, the application of OM results in increased $N_2O$ emissions by soil, according to the Tier 1 method which considers that 1% of the mineral or organic N which is applied on the fields is directly emitted. Hence, the OM application may not result in a reduction of GHG emissions if its N fertilizer efficiency is lower than that of mineral N. In order to study the ability of OM application to reduce GHG emissions, depending on its N fertilizer efficiency, the effects of either a same efficiency as that of mineral N (Figure 4a) or an efficiency 50% lower (Figure 4b) were studied. As expected, the application of OM is an interesting way of reducing the GHG emissions if its N efficiency is as high as that of mineral N. On the contrary, an application of OM with a 50% N fertilizer efficiency, compared with mineral N, results in increased GHG emissions. The N fertilizer efficiency of OM is usually lower than that of mineral N (Leterme and Morvan, 2011). Hence, the application of OM may not be an effective way of reducing GHG emissions, as long as the $N_2O$ emission factors used in the calculation for organic and mineral N applications are



the same. However, these emission factors should be reconsidered, because a unique value for all OM is probably not relevant. One should expect low emission factors for OM with slow N mineralization rates and hence low N fertilizer efficiencies.

Figure 4 – Effect of the application of organic matter (OM) on oilseed rape crop on GHG emissions of




biodiesel

The emissions calculated with the actual OM applications (control) were compared to those of fields receiving 50 kgN ha$^{-1}$ more as organic matter with a fertilizer efficiency as high as that of mineral N ((a), OM 100%) or 50% lower ((b), OM 50%).

## Conclusion

The study clearly showed that the 50% GHG saving criteria cannot be achieved each year, in each of the main French regions producing oilseed rape, without improvements of crop management. The possibility to reduce the GHG emissions by improving the efficiency of mineral N fertilization was demonstrated, while the application of organic matter appeared to be largely ineffective as long as the methods to estimate $N_2O$ emissions are not improved.

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