Are organic suckler cattle farming systems more sustainable than conventional systems? Productive, environmental and economic performances assessments: a model-based study

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Abstract: *The conversion to OF for three specialized suckler cattle farming systems was simulated by coupling an economic optimization model ("Opt'INRA") with a model assessing non-renewable energy (NRE) consumption and greenhouse gas (GHG) emissions ("PLANETE"). Based on average prices over 2004-2008, and after adaptation of the production system, we analyzed the productive, environmental and economic impacts of the conversion process. The ban on chemical fertilisers entails a drop in farm area productivity. For these specialized farms, meat production decreased by 19 to 37% depending on the initial level of intensification. The reduced use of inputs results in a 23 to 45% drop in non-renewable energy consumption per hectare and a 5 to 16% drop per ton of live weight produced. Due to its methane production, the cow is the biggest driver of GHG emissions. The shift to OF does significantly not affect gross GHG emissions per ton of live weight produced, but, taking into account carbon sequestration in grasslands, net GHG emissions could be lower for OF systems. The lower productivity per hectare (less animals reared per ha) allows a 26 to 34% reduction in net GHG emissions per hectare of farm area. Economically, the drop in productivity is not compensated by the gain in the meat selling price (+5 to +10%), gross farm product drops by 9 to 16%, and the lower use of inputs entails a strong drop in operational costs: -9 to -52%. Farm income falls more than 20% (-7 to -46%).*

Keywords: *Beef production, organic farming, greenhouse gas, non-renewable energy, economics, farm model*

Introduction

Cattle farming has been singled out as a global-scale driver of global warming due to the levels of greenhouse gas (GHG) emissions generated. De Vries and De Boer (2009) showed that the production of one kg of beef used more land and energy and had a higher global warming potential than the production of one kg of pork, chicken, egg or milk from non-organic production systems.

Organic farming (OF) is perceived to be a more sustainable production system, performing better than conventional farming in terms of nitrogen losses, pesticide risk, herbaceous plant biodiversity (Pacini et al., 2003; Bengtsson et al., 2005) and water use (Wood et al., 2006). Although various studies have demonstrated the technical and economic relevance of organic suckler cattle farming systems (Veysset et al., 2009, Pavie & Lafeuille, 2009), as of 2008, only 1.5% of the French suckler cows are OF-certified. Farmers looking to convert to OF need not only technical but also economic and environmental references.

In farming, productive and economic performance assessments and environmental performance assessments are inseparably linked. The main objective of this study was to assess the farming system adaptations required in converting to OF, together with the consequences in terms of economic performance and the impacts on non-renewable energy (NRE) consumption and greenhouse gas emissions in three beef production systems employed in the Charolais area.

Given this objective, we opted to use a linear programming-based optimization model. Various different LP models have already been developed for assessing the economic and environmental performance of farming systems (Janssen & Van Ittertum, 2007), several of which have assessed the ecological and/or economic benefits of switching to organic farming (Benoit & Veysset, 2003; Pacini et al., 2004; Kerselaers et al., 2007). The few models focused on beef production were developed to assess fodder systems and alternative feed regimens (Nielsen & Kristensen, 2007).

In order to study the revenue-maximizing production system adaptations required in response to the conversion to OF and to assess economic and environmental performance, we used models coupled by Veysset et al. (2010) to account for suckler farming system diversity: (i) the economic optimization model and (ii) an environmental assessment model.

Materials and methods

The models used

We modeled and assessed the different farming systems in the Charolais area using the Opt'INRA Charolais systems optimization model (Veysset et al., 2005). This model, which was built by linear programming in Excel, optimizes the production system in order to maximize the gross profit margin for Charolais-based mixed crop-livestock farms running either calf-to-weanling systems (suckler cow farms rearing progeny to 9 to 18 months and selling to specialized fatteners, especially in Italy) or calf-to-beef systems (suckler cow farms rearing progeny to slaughter). Opt'INRA integrates all the animal and crop farming activities found in the Charolais basin, together with the different CAP and agro-environmental premiums with their allocation rules. All the activities are linked and bounded by different constraints: structural (useable area, arable land, etc.), agronomic (cropping plan, previous use, etc.), zootechnical (replacement rate, mortality and numerical productivity, feed requirements, etc.) and administrative (premiums). Opt'INRA determines the combination of activities that meet all the constraints and maximize gross profit margin.

The optimal farming system derived from Opt'INRA requires data input on the equipment base and on the number of hours in use for each item of equipment. Each farm task (ploughing, tillage, seeding, harvest, product handling, etc.) is covered by a list of various items of equipment of different size and power, and for which decision rules are given. The model therefore selects the equipment needed for the system defined. Likewise, a specific spreadsheet calculates the building floorspace needed depending on the number and type of livestock to be housed and the fodder and farm equipment to be stocked. The calculation-decision rules account for the unit needs of each type of livestock according to whether they are housed in a stall barn or a loose-housing system. Each item of equipment and each building is characterized in terms of its per-hour or per-hectare energy consumption, together with their annual operating costs.

We used the PLANETE model (Bochu, 2002) to assess the non-renewable energy requirements of the defined farming system and quantify its GHG emissions. PLANETE works at farm scale. It compiles and records all the direct and indirect NRE consumption and GHG emissions tied to the farming activity "from cradle to farm gate". The fate of the products "from farm gate to grave", is not included in this assessment.

We distinguish between the consumption of (i) direct NRE, such as petroleum products and electricity consumed on-farm, and (ii) indirect NRE consumed off-farm in producing and transporting the farm's factors of production, including for farm equipment and farm buildings. The energy values are expressed in megajoules (MJ).

Methane (CH_4) and nitrous oxide (N_2O) are the main GHGs emitted by farming. The contribution of each of these three GHGs is captured via an indicator called the Global Warming Potential (GWP), expressed in tons of equivalent CO_2 (tCO_2eq), which is the sum of each of the gases weighted by their respective coefficients of equivalence, i.e. 1 t CO_2 = 1, 1 t CH_4 = 25, 1 t N_2O = 298 (IPCC, 2007).

PLANETE is a model built in EXCEL, making it easy to couple with Opt'INRA (figure 1).

The description of the models and the methodology used for coupling has been fully described by Veysset et al. (2010)

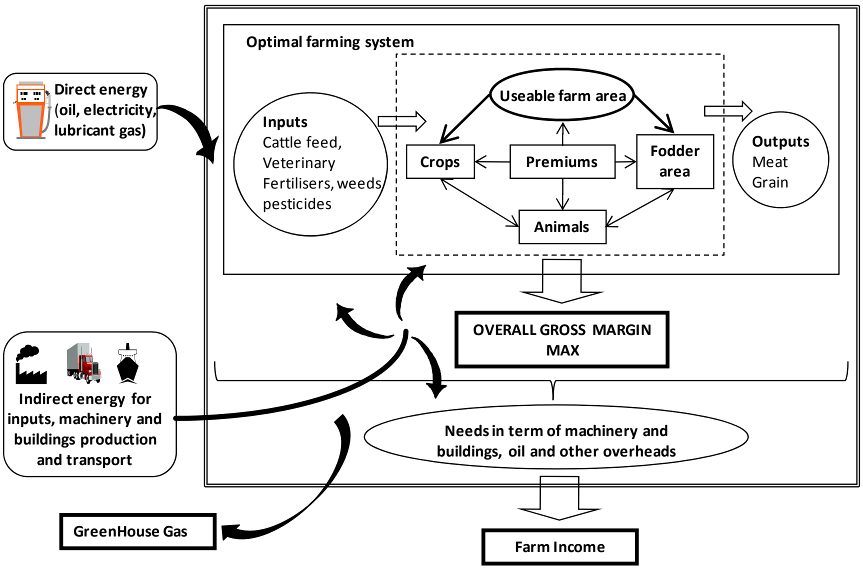

Figure 1: Simplified diagram showing the coupling between an optimization of the farming system maximizing gross margin and a model assessing NRE consumption and GHG emissions.

Gross and net GHG emissions

PLANETE allowed us to determine gross GHG emissions, but carbon sequestration in grasslands (Soussana et al., 2007) is not taken into account.

According to Arrouays et al. (2002), carbon sequestration ranges from 200 kg/ha/yr for a permanent pasture over 30 years old to 500 kg/ha/yr for permanent pasture under 30 years old and temporary pasture. Given that we cannot know the exact age of permanent farm pastures, and given the broad difference between 200 and 500 kg/ha/yr, we opted to work with an average 350 kg/ha/yr to account for carbon sequestration in all permanent pastures. For temporary pasture, we also take into account C export when the pasture is ploughed, i.e. at 1000 kg/ha/yr.

This offsetting of GHG emissions was added to the model depending on pasture type (Dollé et al., 2009), after which net GHG emissions were calculated.

The three farms studied

The Réseaux d'Élevage system run and supervised by the Institut de l'Élevage has pinpointed 25 Charolais beef production systems studied as test cases (Réseau d'Élevage, 2006). We selected three specialized beef-producer test cases for study — not for their representativeness but for the diverse range of systems they covered:

- A: calf-to-weanling system producing males and female store cattle (13 to 16 months old) for the Italian market. This test case A holds 68.4 suckler cow premium entitlements and the buildings have capacity for 77 cows. 100% of 100 ha of the total farm area is devoted to grass; there is no arable land.
- B: calf-to-beef system producing beef steers over 30 months old. 55% of males are castrated, while the others are sold as weaners. Heifers (30 to 36 months old) and cull cows are fattened on-farm. This test case B holds 60.8 suckler cow premium entitlements and the buildings have capacity for 68 cows. Total farm area is 125 ha, of which 90.4 ha (72%) is under permanent grass.
- C: calf-to-beef system producing young bulls (17 months old) and fattened heifers (27 months old). This is an intensive production system using maize silage (stocking rate: 1.60 LU/ha fodder area). This test case C holds 102.6 suckler cow premium entitlements and the buildings have capacity for 110 cows. Total farm area is 155 ha, of which 100 ha (64%) is under

permanent grass. The storage capacity for the maize silage is 130 tons of dry matter (approximately 12 ha).

Analyses of NRE consumption and GHG emissions were carried out with the optimized systems from Opt'INRA. Economic data (input and output prices) are the 4-year averages (2004-2008 excluding 2007). The baseline CAP setting is the 2003 Luxemburg reform. These optimized conventional systems gave a basis for comparisons with the OF systems for the same farms under the same economic and CAP conditions.

Conversion to OF: technical and market hypothesis

The OF principles and constraints were transposed into Opt'INRA. Since plant nitrogen supply is a key factor in OF, we included an N-balance constraint (Simon & Le Corre, 1992). The model can balance this N-balance, either by buying in organic N fertiliser (the unit of organic N costs about 10 times more than the unit of chemical N) and/or by choosing an optimal cropping plan (Veysset, 2002). The ban on chemical fertilizers entails a drop in pasture and cereals yield, from 15% and 25% to 50%.

Observations in a conventional and OF suckler cattle farms network (Veysset at al., 2009) showed that the shift to OF has no impact on herd productivity criteria. However, under the more extensive production system (less concentrates), the liveweight of the animals sold at the same age is 2 to 5% lower.

Because the OF specifications limit the indoor fattening period to three months and at most 1/5 of their lifetime, we did not take into account the production of fattened young bulls and heifers less than 30 months of age. Store animals were valued at conventional farm gate prices (no specific market). Only fattened cull cows, fattened steers and heifers over 30 months old are valued as OF products. We allowed for the possibility of castrating males even on holdings where this had never been previous practice. Castration was limited to 50% of the males of each generation, which is the level usually found among livestock farmers.

Table 1 summarizes the weights of the animals and the yields and prices of the main inputs and outputs used in this study to calibrate our model, for both conventional systems and OF projections.

Table 1. Animals weight, yields, inputs and output prices used for the conventional and OF systems.

		Conventional	Organic farming
Animals sold			
Weaner males 10 months old	Kg live weight*€/kg lw	380*2.45	350*2.35
Weaner males 13 months old	Kg live weight*€/kg lw	473*2.35	406*2.40
Young store bulls 16 months old	Kg live weight*€/kg lw	490*2.35	436*2.40
Baby beef 17 months old	Kg carcass*€/kg cc	429*3.25	Not possible
Beef steers 28 months old	Kg carcass*€/kg cc	452*3.45	Not possible
Beef steers 31 months old	Kg carcass*€/kg cc	476*3.55	430*3.75
Beef steers 36 months old	Kg carcass*€/kg cc	482*3.58	442*3.80
Store cull cows	Kg live weight*€/kg lw	680*1.70	650*1.60
Fattened cull cows	Kg carcass*€/kg cc	435*3.30	405*3.65
Weaner females 8 months old	Kg live weight*€/kg lw	277*2.35	270*2.20
Weaner females 13 months old	Kg live weight*€/kg lw	353*2.25	331*2.20
Store heifers 16 months old	Kg live weight*€/kg lw	418*2.15	393*2.10
Beef heifers 27 months old	Kg carcass*€/kg cc	371*3.55	Not possible
Beef heifers 31 months old	Kg carcass*€/kg cc	378*3.65	370*3.80
Beef heifers 36 months old	Kg carcass*€/kg cc	394*3.75	385*3.90
Crops sold			
Cereals	t/ha*€/t	5.5*106	2.9*210
Pasture yield			
Permanent pasture	t dry matter/ha	5.35 to 7.85	4.30 to 6.30
Temporary pasture	t dry matter/ha	5.10 to 5.70	3.30 to 4.30
Purchased feed and fertilizers			
Soya meal	€/t	300	700
Cereals	€/t	200	390
Nitrogen units	€/kg	0.75 (Chemical)	7.00 (Organic)

Opt’INRA was applied in a single-period approach. We started from a stable conventional situation and arrived at a stable OF situation. The conversion period was not taken into account. The only factors changing are production constraints, inputs, and farm product prices. Farm structure (size, labour force and right to produce) was considered a constant.

Expression of results and analytical criteria

The farm-scale energy audit covers all NRE consumption over one year, expressed in MJ, relative to the production of 1 ton (1000 kg) of live weight (LW) over one year (MJ/t LW). We also calculated NRE consumption per ha of farmland devoted to cattle production (ha “bovine” = fodder area + home-consumed cereals).

In the same way, GHG emissions are expressed in tons of equivalent CO_2 per ton of live weight produced (tCO_2eq/t LW) and per ha of farmland devoted to cattle production.

Taking the gross profit margin generated by Opt’INRA, deducting the specific mechanization and building costs and other overheads (independent of the farm system deployed) gives the farm income of the test case studied.

Results

Production systems and farm income (table 2)

Table 2. Opt’INRA outputs: technical and economic results of the 3 farms studied for conventional (Conv.) and OF systems.

	A: calf-to-weanling 100% grassland farm		B: calf-to-beef. Beef steers production		C: calf-to-beef. Intensive baby beef production	
	Conv.	OF	Conv.	OF	Conv.	OF
Total farm area ha	100	100	125	125	155	155
Cash crops ha	**0.0**	**=**	**0.0**	**0.0**	**0.0**	**4.1**
Grain home-consumed ha	0.0	=	15.8	16.6	35.8	18.0
Fodder area ha	100.0	=	109.2	108.4	119.2	132.9
including maize silage	*0.0*	*=*	*1.8*	*7.1*	*11.0*	*9.8*
Hay + grass silage ha	45.4	52.6	54.0	54.5	42.4	72.5
Number of calvings	**73**	**56**	**68**	**58**	**107**	**80**
Livestock Units LU	107.4	95.9	130.6	112.6	192.6	142.3
Stocking rate LU/ha ”bovine”[a]	**1.07**	**0.96**	**1.04**	**0.90**	**1.24**	**0.94**
Males sold[b]	W13	W16	W13+Bs31	=	Bb17	W13+Bs31
Heifers sold[c]	Sh16	Bh31	Bh36	Bh31	Bh27	Bh31
% cull cows fattened	30	=	100	=	100	100
Concentrates kg/LU	473	357	743	422	1 248	374
including purchased %	*100*	*100*	*11*	*0*	*14*	*0*
Live weight (LW) produced kg	**35,091**	**28,404**	**41,268**	**33,584**	**69,334**	**43,941**
LW produced kg/ha ”bovine”[a]	**351**	**284**	**330**	**269**	**447**	**291**
Grain sold t.	**-**	**-**	**-**	**-**	**-**	**12.2**
Bovine gross margin €/LU	607	549	604	623	602	686
Fodder area gross margin €/ha	673	571	716	676	894	743
Crop gross margin €/ha	-	-	-	-	-	517
Total product €	110,853	97,954	132,646	120,309	199,422	167,008
Operational costs €	30,027	27,376	27,745	16,740	52,506	24,967
Overall gross margin €	**80,826**	**70,579**	**104,901**	**103,569**	**146,915**	**142,041**
Over-head costs €	60,143	59,318	76,480	77,121	99,123	99,023
Including mechanisation €	***20,843***	***20,018***	***27,890***	***28,621***	***32,783***	***32,683***
Farm income €	**20,683**	**11,261**	**28,422**	**26,448**	**47,792**	**43,019**

[a] ha “bovine”: total area devoted to the herd = fodder area + cereals home-consumed

[b] males sold: W10=weaners 10-month-old, W13=weaners 13-month-old, W16=weaners 16-month-old, Bb17=baby beef 17-month-old, Bs31=beef steers 31-month-old, Bs36=beef steers 36-month-old.

[c] females sold: W8=weaners 8-month-old, Sh16=store heifers 16-month-old, Bh27=beef heifers 27-month-old, Bh31=beef heifers 31-month-old, Bh36=beef heifers 36-month-old.

Farm A: As this all-grass system does not produce its own concentrates, it has to buy them if it wants to fatten some animals. The model chooses to fatten all the heifers but only 30% of the cull cows. The males are all sold as weaners. Calvings decrease by 23% and stocking rate decreases 10%. Live weight produced drops 19% and gross farm product decreases 12%. The quantity of concentrates per LU decreases by 25%, but due to price increases in purchased concentrates, the concentrates cost per LU increases by 33% (140 €/LU *vs* 105). The lower number of LU and the savings in chemical fertilizers makes it possible to cut operational costs by 9%. However, farm income suffered the highest drop of the three test case scenarios: -46%, i.e. -94 €/ha.

Farm B: The adaptations made consist in decreasing the number of calvings (-15%) and producing younger beef heifers (31-months old) to adapt stocking rate. The kg of live weight produced decreases by 19%. Opt'INRA chooses to reallocate grassland over to maize silage and grain, the OF system can decrease the quantity of concentrates per LU by 43%. This system becomes feed self-sufficient. Operational costs decrease by 40% while gross farm product only decreases 9%, and overall gross margin close to that of the conventional system. However, due to the higher area under grain and maize, mechanization costs are increased 3%. Farm income decreases by 7%, i.e. -16 €/ha.

Farm C: Since this farm is the most intensive conventional system, the shift to OF entails the highest drop in number of calvings (-25%) and stocking rate (-24%). The OF system produces 31-month-old beef steers and heifers which are fattened mainly with grass. Concentrate requirements per LU decrease by 70% (374 kg/LU) and the area devoted to home-consumed cereals decreases by 50% (18 ha) while the area under grass increases by 14% (123.1 ha *vs* 108.2). The system can release 4.1 ha to cash crops. The total live weight produced decreases by 37%, but 12.2 tons of grain are sold. Farm product decreases by 16% and operational costs are cut by 52%. This farm undergoes the highest changes in the system, and overall, the drop in the farm income is 10% (-31 €/ha).

For all the farms where grain production is possible, a mixture of cereals/protein-rich plants is prioritized in order to supply nitrogen to the system (soil and animals). Unlike conventional systems, no OF systems exclusively grow one cereal only.

Non-renewable energy consumption (table 3)

Table 3. non-renewable energy consumed for beef production for conventional (Conv.) and OF systems.

	A: calf-to-weanling 100% grassland farm		B: calf-to-beef. Beef steers production		C: calf-to-beef. Intensive baby beef production	
	Conv.	OF	Conv.	OF	Conv.	OF
Direct energy (MJ/t LW)						
Fuel & lubricant	7962	9671	10,971	13,069	9080	12,199
Electricity & water	2320	2471	2196	2369	1766	1915
Indirect energy (MJ/t LW)						
Purchased feed	4351	3430	1059	105	1813	293
Artificial fertilizers	4261	648	7559	621	7906	451
Seeds & treatments	0	0	797	1013	1132	924
Veterinary & various raising inputs	1952	2018	1826	2018	1628	2051
Machinery	4396	5456	7051	8141	5622	5793
Buildings	2011	2107	2024	2116	1807	2196
TOTAL MJ/t LW	**27,254**	**25,801**	**33,483**	**29,452**	**30,755**	**25,821**
TOTAL MJ/ha „bovine“	**9564**	**7329**	**11,054**	**7913**	**13,757**	**7518**

Conventional systems

NRE consumption required to produce 1 t of live weight ranges from 27,254 to 33,483 MJ. Petroleum products (fuel, lubricants) are the main consumption input, responsible for around 30% of total NRE consumption. The second-highest consumption input is fertilizers and soil improvers, at 16 to 26% of total NRE consumption, almost level with farm equipment inputs (NRE used in manufacturing and delivering the farm equipment). Feed purchases account for only 3 to 16% of NRE consumption. Miscellaneous other process procurements required for farming livestock (veterinary products, salt/minerals) and harvesting fodder (plastic bale wraps, strings) account for 6 to 7% of total NRE consumption. Depreciation of the energy required to build the farm buildings represents only 5 to 7% of NRE consumption. Finally, the list is rounded up by purchases of seed and plant protection agents, which account for only 0 to 2.5% of the NRE consumed to produce 1 ton of live weight.

The most energy-efficient beef production farm was the all-grass system (test case A). This farm was forced to buy in all its feed (4,351 MJ/t LW), but demonstrated some of the lowest consumption levels for fuel, fertilizer and equipment (7,962, 4,261 and 4,396 MJ/t LW, respectively).

The most intensive system (farm C) was the second-most energy-efficient beef production farm. Fertilizer and feed purchases account for a high proportion of NRE consumption, but the weights of the fuel, mechanization and building factors are lower than in the other systems.

Mechanization, which goes in tandem with fuel, is the primary source of variability in results on NRE consumption for 1 ton of live weight produced, with feed purchases coming second.

Crossing the data against farm area used by the herd reveals a direct link between farm intensification level (kg LW produced/ha “bovine”) and NRE consumption, which varies from 9,564 (farm A) to 13,757 (farm C) MJ/ha “bovine”. The leading influencing factor remains fuel, with fertilizers ranking second.

Organic farming systems

This reduced use of allied crop input (fertilizers, seed, treatments) under organic systems, especially the non-use of chemical fertilizers, leads to a 60%-70% drop in the consumption of NRE/t LW related to these items.

Farms B and C are almost completely self-sufficient on animal feed, as only minerals are bought in. Consumption of NRE related to the purchase of food therefore drops almost 90%.

At constant surface area, organic and conventional systems share almost identical equipment requirements. As total live weight production drops, the mechanization/t LW item increases by 18%, 13% and 8% for farms A, B, and C, respectively. The direct energy/t LW item increases 17% (farm B) and 30% (farm C).

All in all, the shift to organic farming entails a significant decrease (-5 to -20%) in the consumption of NRE/t LW produced, under all systems. This fall in consumption of NRE/t LW was only 5% for the all-grass system (farm A), which is less intensive and uses less inputs that the conventional system.

Since OF systems are less intensive (stocking rate: -10% to -24%), they use far fewer inputs per ha “bovine”. The consumption of direct energy per ha thus shows a 5%-15% decrease, while consumption of NRE per ha linked to crop inputs shows a 65%-80% decrease. Total NRE consumption per ha “bovine” is 23%-45% lower in OF systems than conventional systems.

Greenhouse gas emissions (table 4)

Conventional systems

The conventional Charolais suckler cattle farms systems produce 14.9-17.2 tCO_2eq/ton of live weight produced over one year and 5.58-6.68 tCO_2eq/ha “bovine”.

Methane emissions tied exclusively to ruminant farming (enteric fermentation and manure management) are the main driver of gross GHG emissions, at around 60% (from 58 to 66%). Ruminant activities are also responsible for over 50% of farm N_2O emissions, principally from urine and faecal waste at pasture. Livestock is responsible for nearly 75% of farm-scale gross emissions (69 to 80%), followed by farm inputs, especially mineral fertilizers which alone account for 5 to 11%. The combustion of direct energy sources (fuel and electricity) is accounts for 27% of CO_2 emissions but only 4% of farm-scale GWP.

Cows are the biggest driver of GHG emissions in the herd. The least GHG-emitting farm in terms of ton of LW produced is therefore C, where all animals are fattened and where cows account for 48% of LU. Gross GHG emissions are 14.9 tCO_2eq/t LW for C, with CH_4 representing 59% of these emissions. Farms A, which sells most of its animals as store cattle and where cows represent 57% of total LU, generate 17.2 tCO_2eq/t LW.

Stocking rate (number of animals raised and produced per hectare, and thus quantity of live weight produced per hectare) is the main driver of herd-related GHG emissions per ha. The most intensive test case C (1.24 LU/ha “bovine”) is the most gross GHG-emitting farm per ha. With its lowest stocking rate (1.04 LU/ha “bovine”) and calf-to-beef system, B is the lowest gross GHG-emitting farm per ha for cattle production.

Depending on the share-split of permanent and temporary pastures in the total farm area, and thus on the ha of grassland per t LW produced, the carbon offset can be more or less important. With farms A, B, and C producing 2.85, 2.60, and 1.57 ha of grassland/ton LW produced, the offsetting of gross GHG emissions/t LW is 21%, 19%, and 13% respectively. Net GHG emissions ranged from 12.9 (farm C) to 13.6 (farms A and B) tCO_2eq/t LW and from 4.50 (farm B) to 5.79 (farm C) tCO_2eq/ha “bovine”.

Farm C was the lowest gross GHG-emitting farm, but as it contained a lower proportion of grassland, the live weight was produced with more grain and maize than in the other farms, with the result that it showed the lowest carbon offset. Net GHG emissions remained the lowest, but were only 5% lower than for farm A, while gross GHG emissions were 13% lower.

Table 4: greenhouse gas emissions for beef production for conventional (Conv.) and OF systems.

	A: calf-to-weanling 100% grassland farm		B: calf-to-beef. Beef steers production		C: calf-to-beef. Intensive baby beef production	
	Conv.	OF	Conv.	OF	Conv.	OF
CO_2 (tCO_2eq/t LW)	1.9	2.0	2.5	2.5	2.2	2.3
Combustion of direct energy	*0.5*	*0.6*	*0.7*	*0.8*	*0.6*	*0.8*
Inputs making	*1.4*	*1.3*	*1.8*	*1.6*	*1.6*	*1.5*
CH_4 (tCO_2eq/t LW)	11.5	11.4	9.8	10.5	8.8	10.6
N_2O (tCO_2eq/t LW)	3.9	3.6	4.7	3.8	3.9	3.8
Inputs making	*0.2*	*0.0*	*0.3*	*0.0*	*0.4*	*0.0*
Nitrogen application on farm area	*1.4*	*1.1*	*2.0*	*1.3*	*1.6*	*1.4*
Cattle waste	*2.3*	*2.5*	*2.3*	*2.4*	*2.0*	*2.4*
Gross GHG emissions (tCO_2eq/t LW)	**17.2**	**17.0**	**16.9**	**16.7**	**14.9**	**16.7**
Gross GHG emissions (tCO_2eq/ha)	**6.05**	**4.83**	**5.58**	**4.48**	**6.68**	**4.85**
C offset % gross GHG emissions	21	27	19	23	13	21
Net GHG emissions (tCO_2eq/t LW)	**13.6**	**12.5**	**13.6**	**12.9**	**12.9**	**13.2**
Net GHG emissions (tCO_2eq/ha)	**4.77**	**3.55**	**4.50**	**3.46**	**5.79**	**3.83**

Organic farming systems

The shift to OF had no significant impact on gross GHG emissions/ton LW produced. As CH_4 is the main driver of GHG emissions, OF has no impact. Indeed, due to the lower live weight production/LU, gross GHG emissions/t LW produced can even prove higher under OF systems, at +12% for farms C.

Due to the lower pasture productivity and thus the lower stocking rates, OF systems use more ha of pastures to produce 1 ton of LW, i.e. +24% (3.52 ha/t LW), +16% (3.02 ha/t LW) and +78% (2.80 ha/t LW) for farms A, B and C, respectively. The offsetting of gross GHG emissions/t LW due to the carbon sequestration ranges from 21% (farm C) to 27% (farm A), i.e. 3.5 to 7.7 points higher than for conventional farming systems.

While gross GHG emissions from OF systems are on a par with or even slightly higher than conventional systems, the net GHG emissions are the same (+2% for farm C) or from 5 to 8% lower for farms B and A, respectively.

As stocking rate is lower under OF systems than on conventional farms, CH_4 emissions per ha “bovine” ranged from 13% to 20% lower. This drop in CH_4 emissions coupled with the reduced use of inputs per ha “bovine” means that the shift to OF leads to a -20% to -27% cut in gross GHG emissions and a -23% to -34% cut in net GHG emissions.

Discussion

Given that fuel, fertilizers and farm machinery are the main sources of NRE consumption, there is relatively little latitude for adapting farm systems to minimize these source-uses. The only hope for achieving any genuinely significant impact would be to radically change the systems and dramatically reduce or even totally cut out the inputs. OF is a more energy-efficient system for beef production, as energy is saved on the non-use of chemical fertilizers and other inorganic industrially-produced inputs. Similar patterns are reported for other agricultural products: OF systems use 10-20% less NRE to produce one ton of cereal than conventional systems (Dalgaard et al., 2001, Refsgaard et al., 1998, Bochu, 2007) and 15-30% less NRE to produce 1000 liters of milk (Refsgaard et al., 1998, Cederberg & Mattson, 2000, Grönross et al., 2006, Bochu, 2007). Based on 35 surveys led on farms in southern Germany, Haas et al. (2001) reported that organic farms used 55% less NRE to produce one ton of milk. However, the results on farming monogastric animals show a different pattern: NRE use per kg of pig produced is 40% higher in French OF systems (Basset-Mens & Van der Werf, 2005), whereas for eggs and poultry production in the UK, NRE use per ton is 10% higher in organic systems (Azeez, 2008). However, after analysis of 15 crop and livestock sectors weighted in relation to the UK’s total agricultural output, switching these 15 sectors to organic farming would decrease total NRE consumption by 26% (Azeez, 2008).

The impact of the conversion to OF on the GWP is not really significant per ton of live weight produced. Only a higher proportion of grassland in the farm area can make a difference, as it increases the carbon offset and thus decreases net GHG emissions. Without taking this carbon sequestration into account, Casey & Holden (2006) reported that organic Irish suckler-beef units emit 14% less GHG/t LW. Cederberg & Mattson were unable to draw concrete conclusions on switching milk production to OF, whereas Hass et al. (2001) found the same levels of GHG emission/t milk in organic and intensive systems. GWP seems to be much higher for organic pig production than conventional pig farming, at +70% (Basset-Mens & Van der Werf, 2005).

Most papers have used tons or kg produced as the main functional unit for analyzing the results. In some cases, the surface area of agricultural land used for the production could be a useful scalar to analyze the results, especially where the preservation of abiotic resources (water, soil, etc.) is a major issue. Consumption of NRE and net GHG emissions per ha devoted to beef production are much lower under organic systems. These better per-ha results for OF are mainly due to the lower stocking rate, and thus to lower outputs per ha for organic systems, but also to the better N efficiency (Olesen at al., 2006).

This lower productivity of organic systems is not totally compensated by a cost savings on Charolais suckler cattle farms, and at constant structure, farm income can drop significantly, to levels unacceptable for farmers. For the three test-cases studied in this paper, the drop in farm income ranged from -16 Euros/ha (farm B) to -94 Euros/ha (farm A). If OF offers better per-ha environmental performance, then switching to OF could be made financially viable. Given the twin global challenges of ensuring food security and reducing GHG emissions, the main policy imperative is for decision makers to explicitly combine these two goals (Garnett, 2009). Under the Common Agriculture Policy “Health Check” system, France has decided to redirect subsidies towards grassland livestock production systems and sustainable farming (Ministère de l’Agriculture et de la Pêche, 2009). In this context, OF-certified grassland areas are earmarked to receive aid amounting to 80 to 100 Euros/ha.

Conclusions

Improving energy efficiency, self-reliance and carbon footprint are some of many principles and objectives in organic agriculture. These objectives need to be balanced against other objectives, such as agricultural output and farm income (Niggli et al., 2008).

Assessments of farm production systems should be fully holistic — environmental assessments cannot be divorced from economic assessments. Reducing the environmental footprint of a cattle farm only makes sense if the farm is economically viable and thus able to run sustainably.

Depending on whether analysis is focused on production and market, resources protection, or farm or territory-wide economy, the decision maker will give more weight to certain criteria, but should not ignore the others when seeking the best compromise.

Whole-farm models coupling biophysical, economic and environmental models offer powerful tools for carrying out multicriteria analysis on the opportunity to switch to a new production system.

Global warming is a real problem, and beef production is a central contributor. However, the differences between intensive indoor systems and grass-based pasture systems mean they do not have the same impacts. In depressed grassland zones and highland areas where grass is the sole resource, livestock production is not in competition with other use demands of the agricultural area, and more importantly, it allows this land to be maintained under grass (carbon sequestration) and human activities. A methodological challenge for the future assessment of farming systems is to conduct multicriteria analyses that also integrate social aspects (Siciliano, 2009).

References

Arrouays D, Balesdent J., Germon J.C., Jayet P.A., Soussana J.F. and P. Stengel (2002) Contribution à la lutte contre l'effet de serre. Stocker du carbone dans les sols agricoles de France ? Expertise scientifique collective. Rapport INRA 332p.

Azeez G.S.E. (2008) The comparative energy efficiency of organic farming. International Conference on Organic Agriculture and Climate Change, Enita of Clermont, ABio Doc, France, April 17-18th.

Basset-Mens C. and H. Van der Werf (2005) Scenario-based environmental assessment of farming systems: the case of pig production in France. *Agriculture, Ecosystems and Environment* 105: 127-144.

Bengtsson J., Ahnström J. and A.C. Weibull (2005) The effects of organic agriculture on biodiversity and abundance: a meta-analysis. *Journal of Applied Ecology* 42(2): 2611-269.

Benoit M. and P. Veysset (2003) Conversion of cattle and sheep suckler farming to organic farming: adaptation of the farming system and its economic consequences. *Livestock Production Science* 80: 141-152.

Bochu J.L. (2002) PLANETE : Méthode pour l'analyse énergétique des exploitations agricoles et l'évaluation des émissions de gaz à effet de serre. Colloque national : Quels diagnostics pour quelles actions agroenvironnementales ? 10 & 11 octobre, Solagro, 68-80.

Bochu J.L. (2007) Synthèse 2006 des bilans PLANETE. Consommation d'énergie et émissions des GES des exploitations agricoles ayant réalisé un bilan PLANETE. Rapport final. ADEME, Ministère de l'Agriculture et de la Pêche.

Casey J.W.and N.M. Holden (2006) Greenhouse gas emissions from conventional, agri-environmental scheme, and organic Irish suckler-beef units. *Journal of Environmental Quality* 35: 231-239.

Cederberg C. and B. Mattsson (2000) Life cycle assessment of milk production – a comparison of conventional and organic farming. *Journal of Cleaner Production* 8: 49-60.

Dalgaard T., Halberg N. and J.R. Porter (2001) A model for fossil energy use in Danish agriculture used to compare organic and conventional farming. *Agriculture, Ecosystems and Environment* 87: 51-65.

De Vries M. and I.J.M. De Boer (2009) Comparing environmental impacts for livestock products: a review of life cycle assessments. *Livestock Science*, in press, doi:10.1016/j.livsci.2009.11.007

Dollé J.B., Gac A. and A. Le Gall (2009) L'empreinte carbone du lait et de la viande bovine. *Rencontres Recherches Ruminants* 16: 233-236.

Garnett T. (2009) Livestock-related greenhouse gas emissions: impacts and options for policy makers. *Environmental Science & Policy* 12: 491-503.

Grönroos J., Seppälä J., Voutilainen P., Seuri P. and K. Koikkalainen (2006) Energy use in conventional and organic milk and rye bread production in Finland. *Agriculture, Ecosystems and Environment* 117: 109-118.

Haas G., Wetterich F. and U. Köpke (2001) Comparative intensive, extensified and organic grassland farming in southern Germany by process life cycle assessment. *Agriculture, Ecosystems and Environment* 83: 43-53.

Intergovernmental Panel on Climate Change. (2007) 2006 IPCC Guidelines for National Greenhouse Gas Inventories. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

Janssen S. and M. Van Ittersum (2007) Assessing farm innovations and responses to policies: A review of bio-economic farm models. *Agricultural Systems* 94: 622-636.

Kerselaers E., De Cock L., Lauwers L. and G. Van Huylenbroeck (2007) Modeling farm-level economic potential for conversion to organic farming. *Agricultural Systems* 94: 671-682.

Ministère de l'Agriculture et de la Pêche (2009) Bilan de santé de la PAC : mise en oeuvre. Pour une PAC préventive, juste et durable http://agriculture.gouv.fr/sections/presse/communiques/legitimite-nouvelle-pour/downloadFile/FichierAttache_1_f0/Bilandesantefrance.pdf?nocache=1235412961.28

Niggli U. Slabe A., Schmid O., Halberg N. and M. Schlüter (2008) Vision for an organic food and farming research agenda 2025. Organic knowledge for the future. *Technology Platform Organics*, http://orgprints.org/13439/

Nielsen B.K. and A.R. Kristensen (2007) Optimal decisions in organic beef production from steers – Effects of criterion of optimality and price changes. *Livestock Science* 110: 25-32.

Olesen J.E., Schelde K., Weiske A., Weisbjerg M.R., Asman W.A.H. and J. Djurhuus (2006) Modelling greenhouse gas emissions from European conventional and organic dairy farms. *Agriculture, Ecosystems and Environment* 112: 207-220.

Pacini C., Wossink A., Giesen G., Vazzana C. and R. Huirne (2003) Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and field-scale analysis. *Agriculture, Ecosystems and Environment* 95: 273-288.

Pacini C., Giesen G., Wossink A., Omodei-Zorini L. and R. Huirne (2004) The EU's Agenda 2000 reform and the sustainability of organic farming in Tuscany: ecological-economic modelling at field and farm level. *Agricultural Systems* 80: 171-197.

Pavie J. and O. Lafeuille (2009) Valorisation des données technico-économiques des exploitations allaitantes biologiques suivies dans les réseaux d'élevage. Evolutions d'un échantillon constant sur 7 campagnes (2000-2006). Réseaux d'élevage pour le conseil et la prospective, Collection Références, Institut de l'Elevage et Chambres d'Agriculture.

Refsgaard K, Halberg N. and E.S. Kristensen (1998) Energy utilisation in crop and dairy production in organic and conventional livestock production systems. *Agricultural Systems* 57(4): 599-630.

Réseau d'Elevage Charolais (2006) Bassin Charolais. Conjoncture économique des systèmes bovin viande, campagne 2006. Document, Chambre d'Agriculture, Institut de l'Elevage, 50p.

Siciliano G. (2009) Social multicriteria evaluation of farming practices in the presence of soil degradation. A case study in southern Tuscany, Italy. *Environment, Development and Sustainability* 11(6): 1107-1133.

Simon J.C. and L. Le Corre (1992) Le bilan apparent de l'azote à l'échelle de l'exploitation agricole: méthodologie, exemples de résultats. *Fourrages* 129: 79-94.

Soussana J.F., Fuhrer J., Jones M. and A. Van Amstel (2007) The greenhouse gas balance of grasslands in Europe. *Agriculture, Ecosystems & Environment* 121: 1-4.

Veysset P. (2002) Conversion of mixed holdings (crop/suckler cattle) to organic farming: finding a balance between fodder and cash crops and economic consequences. In: Proceedings of the 14th Organic World Congress, IFOAM, 117.

Veysset P., Bébin D. and M. Lherm (2005) Adaptation to Agenda 2000 (CAP reform) and optimization of the farming system of French suckler cattle farms in the Charolais area: a model-based study. *Agricultural Systems* 83: 179-202.

Veysset P., Bécherel F. and D. Bébin (2009) Elevage biologique de bovins allaitants dans le Massif Central : resultants technico-économiques et identifications des principaux verrous. *Inra Productions Animales* 22(3): 189-196.

Veysset P., Lherm M. and D. Bébin (2010) Energy consumption, greenhouse gas emissions and economic performance assessments in French Charolais suckler cattle farms: Model-based analysis and forecast. *Agricultural Systems* 103: 41-50.

Wood R., Lenzen M., Dey C. and S. Lundie (2006) A comparative study of some environmental impacts of conventional and organic farming in Australia. *Agricultural Systems* 89: 324-348.