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THE PREVIOUS COMMON AGRICULTURAL POLICY (2003-2013) REDUCED FRENCH AGRICULTURAL EMISSIONS

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This current document presents all appendices and methodologies used by the authors.

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ACRONYMS

ADEME: French Environment and Energy Management Agency (*Agence de l'Environnement et de la Maîtrise de l'Energie*)

AEM: Agri-Environmental Measure

AG: Artificial Grassland

BAU: Business-as-usual

CAP: Common Agricultural Policy

CF: Conventional farming

CH_4: Methane

CITEPA: French Interprofessional Technical Centre for Studies on Air Pollution (*Centre Interprofessionnel Technique d'Etudes de la Pollution Atmosphérique*)

CO_2 : Carbon dioxide

EAFRD: European Agricultural Fund for Rural Development

EAGF: European Agricultural Guarantee Fund

EF: Emission Factor

GAEC: Good Agricultural and Environmental Conditions

GWP: Global Warming Potential

OF: Organic farming

GHG: Greenhouse gas

ICHN: Compensatory allowances for natural disadvantages (*Indemnités compensatoires d'handicaps naturels*)

INRA: French National Institute for Agricultural Research (*Institut National de la Recherche Agronomique*)

IPCC: Intergovernmental Panel on Climate Change

LSU: Large Livestock Unit

LULUCF: Land Use, Land Use Change and Forestry

MAAF: French Ministry for Agriculture, Agri-food and Forestry (*Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt*)

Mha: Millions of hectares

N_2O: Nitrous oxide

NH_3: Ammonia

PDRH: French Rural Development Programme (*Programme de Développement Rural Hexagonal*)

PHAE: Agri-environmental grassland premium (*Prime Herbagère Agroenvironnementale*)

PMBE: Plan to modernise livestock buildings (*Plan de Modernisation des Bâtiments d'Elevage*)

PMTVA: Premium for maintaining a herd of suckler cows (*Prime au Maintien de Troupeau de Vaches Allaitantes*)

PPE: Energy performance plan (*Plan de Performance Energétique*)

PG: Permanent Grassland

PVE: Green environment plan (*Plan Végétal pour l'Environnement*)

SFEI: Low-input forage system (*Système Fourrager Econome en Intrants*)

TG: Temporary Grassland

UAL: Utilised Agricultural Land

APPENDIX I. CALCULATIONS OF TOTAL GHG EMISSIONS IN THE ARABLE SECTOR

Estimation of the various CAP measures' potential for mitigation of GHG emission factors is mainly based on the report (Pellerin et al., 2013a), the emission factors of IPCC guidelines(IPCC, 2006) and the CITEPA national inventory reporting method(CITEPA, 2013a).

a. *Sustainable fertilisation (PPE, PVE and professional training)*

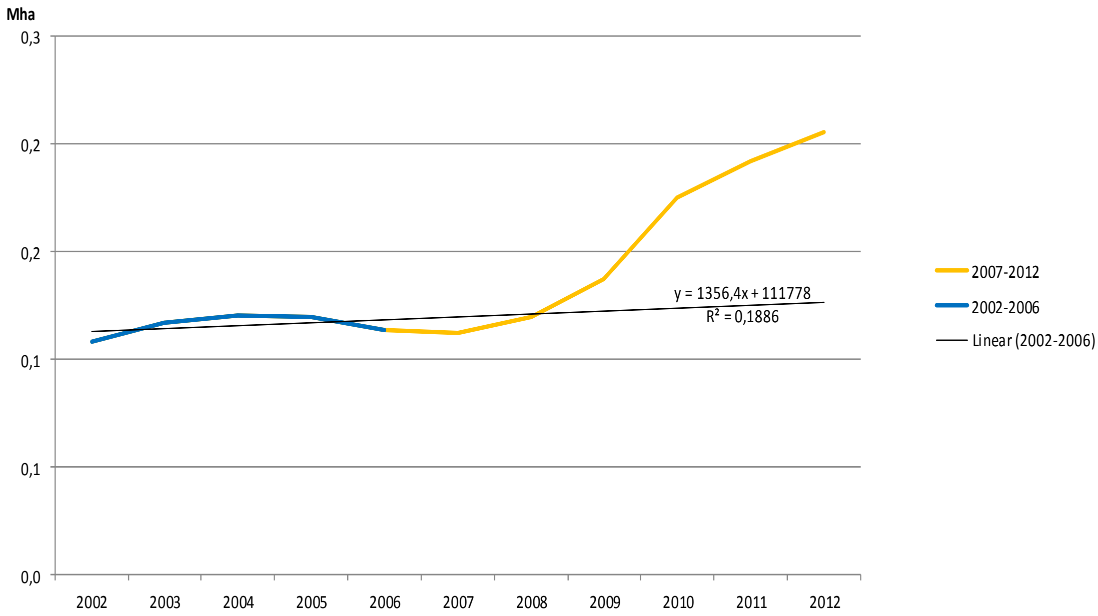
See section (**Erreur ! Source du renvoi introuvable.**).

b. *Pillar 1: “support for organic farming" – crops*

Activity data: surface area of field crops in organic farming

Changes to the surface area of field crops in OF do not present any significant trend (P = 0.48) over the period 2002-2006, although a clear change can be seen in the trend between 2007-2012 (Figure 1, Table 1).

Figure 1. Change in the surface area of field crops in organic farming between 2002 and 2012



Source: CDC Climat Research – Agreste (2013a)

Table 1. Change in the surface area of field crops in organic farming and comparison with projection

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total surface area of field crops (Mha)	14.70	14.66	14.78	14.67	14.55	14.57	14.98	14.99	15.53	15.41	15.06
Surface area in OF (Mha)	0.11	0.12	0.12	0.12	0.11	0.11	0.12	0.14	0.18	0.19	0.21
Surface area in OF projected based on changes in 2002-2006 (Mha)						0.12	0.12	0.12	0.12	0.12	0.12

Source: FAOSTAT, Agence Bio (2012)

Emission factor

Conventional field crops

The emission factor per hectare for conventional practices is deduced from average use of inputs for each field crop (Agreste, 2011), from Pellerin et al. (2013b) for N_2O emissions in the field linked to mineral fertilisation, from the national GHG inventory for N_2O emissions in the field linked to organic fertilisation (CITEPA, 2013a), and from ADEME (2010) for emissions linked to the manufacture of inputs and mechanisation (see appendix III.a).

Organic field crops

N_2O emissions in the field from organic field crops fell by 31% per unit of surface area (Tuomisto et al., 2012). Emissions linked to mechanisation are considered to be unchanged (Guyomard, 2013)[1] and emissions linked to other inputs to be nil, since synthesised inputs are banned under OF rules. Furthermore, the average yield from field crops is estimated at 64.2 q/ha in CF compared with 36.5 q/ha for comparable plots in OF (Guyomard, 2013). The total emissions factor obtained is therefore 60% lower for OF than for CF (Table 2). The difference falls to 30% when emissions are considered in relation to quantities produced. For N_2O emissions in the field per quintal, emissions from OF are 21% higher than CF, which is roughly similar to the 8% recorded by Tuomisto et al. (2012).

Table 2. Emissions factors in CF and OF for field crops

	N2O emission factor in the field (in tCO_2e/ha of UAL/year)	Upstream and mechanisation emission factor (in tCO_2e/ha of UAL/year)	Emission factor (in tCO_2e/tDM)
Conventional farming (CF)	0.98	0.79	0.28
Organic farming (OF)	0.68	0.03	0.19

Estimation of GHG emissions avoided per year (surface area approach)

Emissions avoided = (surface area in OF between 2007-2012 – projected surface area in OF between) x emission factor = (156 915 – 115 848) * (0.98+0.79-0.68-0.03) = - 0.042 $MtCO_2e$/year

[1] Scientific literature is less than clear-cut in this respect. But whatever the case, these emissions represent a minimal share of the total emissions factor.

Estimation of GHG emissions avoided per quantity produced

Considering the results set out above, emissions per quintal of wheat are 30% less in OF, despite a fall in yield estimated at 43%.

c. "Crop residues" GAEC

Each tonne of "unburnt" dry material avoids 0.21 tCO_2e of CH_4 and N_2O emissions. CO_2 emissions are considered to be nil since the combustion source – biomass – is renewable. Emissions factors are taken from CITEPA (2013a). No estimation of GHG quantities avoided per year since the measure is deemed in effective (see section **Erreur ! Source du renvoi introuvable.**).

d. "Buffer strip" GAEC – crops

Activity data: surface area of buffer strips

Buffer strips planted under this GAEC are grassed areas along watercourses. Surface area data are not clearly identified in CAP declarations. The surface area of grass strips is therefore assumed to be 0.25 Mha, corresponding to the maximum technical surface area estimated by Pellerin et al. (2013a), of which 39.6% or 0.099 Mha, is for field crops. This assumes that this GAEC is strictly complied with by farmers.

Emission factor

Chemical inputs (fertilisers and pesticides) may not be used on the grass strips. Neither can organic matter be used on them, although spreading manure and liquid manure was already banned on the edge of watercourses. Emissions linked to fuel consumption are not included, although they are no doubt slightly less. The emission factor linked to inputs is calculated based on average use of mineral fertilisers and pesticides on field crops (see Appendix III.a).

Grass strips are treated in the same way as grasslands by Pellerin et al. (2013a), which is why additional carbon storage in the soil is only possible if the plot was used for crops (see Table 3).

Table 3. GHG emissions avoided by grass strips in field crops

	Emissions factor for N_2O avoided in the field (in tCO_2/ha/year)	Emissions factor for GHGs avoided upstream (in tCO_2/ha/year)	Additional carbon storage (in tCO_2/ha/year)
Grass strips for crops	1.01	0.84	1.8

Sources: Appendix III.a, Pellerin et al. (2013a), ADEME (2011)

Estimation of GHG emissions avoided per year (surface area approach)

Total: 0.099 x (- 1.01 - 0.84 - 1.8) = - 0.36 $MtCO_2e$/year

Estimation of GHG emissions avoided per quantity produced

The reduction in farmed surface area leads to a proportional reduction in yields:

Reduction in yields = $-\frac{surface\,area\,of\,grass\,strips\,for\,field\,crops}{average\,surface\,area\,of\,field\,crops\,(2010-2012)} = -\frac{0.099}{15.33}$ = -0.6%.

Changes in GHG emissions per quantity produced are unaffected for plots which remain farmed, with emissions and yields falling in proportion to the surface area. Emissions per quantity produced fall slightly, however, due to carbon storage in the grassed area:

Total per quintal of wheat: (emissions from the farmed surface area – sequestration in the grass strip) / quantity produced from the farmed surface area = (average emissions x 0.994 - 0.006 * 1.8) / (average yield * 0.994) = 0.287 tCO_2e/tDM or 0.6% less than average emissions per tDM of wheat.

e. "Maintenance of landscape features" GAEC – crops

Activity data: length of hedgerow

See section **Erreur ! Source du renvoi introuvable.**.

Emission factor

It is assumed that no enrichment agent (fertilisers or pesticides) are added to hedgerows. Emissions linked to fuel consumption are slightly higher than for crops, though negligible (Pellerin et al., 2013b). The emission factor linked to inputs is calculated based on average use of mineral fertilisers and pesticides on field crops (see Appendix III.a).

A hectare of field crops including hedgerows is assumed to contain 60 linear metres, taking up 1.2% of the surface area of the land (Pellerin et al., 2013b).

Estimation of GHG emissions avoided per hectare (surface area approach) and per quantity produced

The method is the same as for grass strips. The results are summarised in Table 4.

Table 4. GHG emissions avoided by the planting of hedgerows for field crops

	Avoided emissions of N_2O from agricultural soils	Upstream GHG emissions avoided	GHG emissions from livestock	Additional carbon storage	Total
En tCO2e/ha[1]/yr	-0,01	-0,01	0,00	-0,55	-0,57
Total (MtCO2e/yr)	0,00	0,00	0,00	0,00	0,00
Per product quantity	-30,8 % per quintal of wheat. Fall in yield of -1,2 %.				

[1] On a basis of 60 linear metres of hedgerow per hectare according to Pellerin et al. (2013).

f. "Minimum land management" GAEC – crops

"Soil and biomass carbon" reference scenario and emission factor

The reference scenario considered is a conversion from crops to forest. The conversion of crops to forest causes changes to carbon stocks in the soil and in biomass. The emission factor linked to these changes is taken directly from the national inventory (CITEPA, 2013c).

Emission factors linked to usage

Apart from changes to carbon stocks, the conversion of crops into forest will remove emissions associated with crop management (fertilisation, etc.) but will lead to new emissions linked to forestry management. Emissions from the various uses of the soil are therefore calculated based on the following assumptions:

- Source: see Appendix III.a.
- forest: emissions linked to forestry operations are not counted. Emissions are therefore nil excluding the change in carbon sequestration.

Estimation of GHG emissions avoided per year (surface area approach)

See section **Erreur ! Source du renvoi introuvable.**.

Assessment per quantity of product

The assessment per quantity of product is difficult to calculate due to the transition from an agricultural product to a forestry product.

g. Rotational agri-environmental measure (RAEM)

Reference scenario

The reference scenario considered is an "average" field crop, managed according to the crop management technique described in appendix III.a.

Emission factors

The sources for the reference scenarios are identical to the rest of the study (see appendix III.a). For additional surface areas registered on the AEM, the only emissions reduction considered is a 36% reduction in the use of phytosanitary products (Reau et al., 2009).

Surface area subject to a PHAE contract

The physical surface area contracted to this AEM is 1.2 Mha. (DG Agriculture, 2011).

Additionality

The AEM's degree of additionality (α, see section **Erreur ! Source du renvoi introuvable.**) is 0.012.

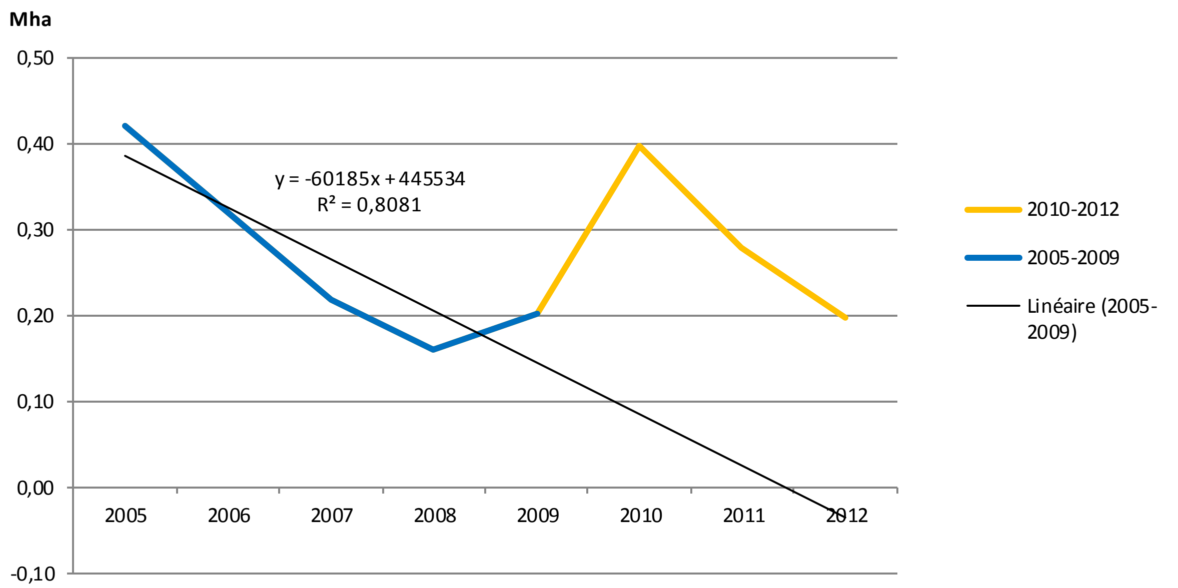
h. Pillar 1: "support for protein crops" – crops

Support for "grain legume" protein crops (crops)

Activity data: surface area of protein crops

Changes in the surface areas of grain legumes present a significant decreasing trend (P = 0.03) over the period 2005-2009, interrupted by implementation of the support for protein crops in 2010 (Figure 2).

Figure 2. Change in the surface area of grain legumes between 2005 and 2012



Source: CDC Climat Research – Agreste (2013a)

The BAU scenario is therefore the linear extrapolation of the 2005-2009 trend for 2010-2012 (Table 5). The negative extrapolated value for 2012 is considered zero (see section **Erreur ! Source du renvoi introuvable.**).

Table 5. Change in protein crops and comparison with projection

	2005	2006	2007	2008	2009	2010	2011	2012
Surface area of protein crops (Mha)	0.422	0.322	0.219	0.160	0.201	0.397	0.278	0.197
Project surface area of protein crops based on changes between 2005-2009 (Mha)						0.084	0.024	0

Agreste (2013a)

Emission factor

Emissions factors are taken directly from Pellerin et al. (2013a) who particularly take account of the induced effect of legumes on the following crops (Table 6).

Table 6. Emissions factors of grain legumes

	N_2O emissions (in $tCO_2e/ha/year$)	Direct CO_2 emissions (in $tCO_2e/ha/year$)	Upstream GHG emissions (in $tCO_2e/ha/year$)
Per hectare of legumes introduced	1.02	0.02	0.95

Estimation of N_2O emissions avoided as a result of support to protein crops

As a result of support for planting grain legumes in field crops:

(0.291 – 0.036) x (-1.02) = - 0.26 $MtCO_2e/year$

Estimation of direct GHG emissions avoided as a result of reduced use of fuel on the farm

(0.291 – 0.036) x (-0.02) = - 0.01 $MtCO_2e/year$

Estimation of induced GHG emissions avoided as a result of reduced use of fertiliser

Emissions factors are taken from Pellerin et al. (2013).

(0.291 – 0.036) x (-0.95) = - 0.24 $MtCO_2e/year$

Estimation of GHG emissions avoided per quantity produced

Pellerin et al. (2013b) estimate the quantity of mineral nitrogen saved by field crops following legumes (average between pea-wheat and pea-rapeseed rotations) at 33 kgN/ha. Pellerin et al. (2012) consider that a previous pea crop also increases the yield of the following crop (wheat) by 8.4 q/ha compared with a previous wheat crop and by 1.9 q/ha compared with a previous rapeseed crop. Similarly to Pellerin et al. (2013b), we estimate the average gain (5.15 q/ha) to be 8% more than the average yield identified in appendix I.b. The result is an estimation of 0.23 tCO2e/tDM for field crops preceded by peas compared with 0.26 tCO2e/tDM on average.

The quantities released per unit of peas are not taken into accounts due to the difficulty in comparing them to emissions per unit of another crop (the quantity of dry material, for example, would disregard the high protein content of peas compared with wheat).

This gives the change in total GHGs for an average tDM for field crops (as a %)

= emissions based on projected surface areas – emissions based on recorded surface areas

$$= \frac{S_{AB\_proj} \times R_{AB} \times FE_{AB\_tMS} + S_{AC\_proj} \times R_{AC} \times FE_{AC\_tMS}}{S_{AB\_proj} \times R_{AB} + S_{AC\_proj} \times R_{AC}} - \frac{S_{AB} \times R_{AB} \times FE_{AB\_tMS} + S_{AC} \times R_{AC} \times FE_{AC\_tMS}}{S_{AB} \times R_{AB} + S_{AC} \times R_{AC}}$$

= 0.04%

Where $S_{prev\_peas\_proj}$, S_{PREV_PEAS}, S_{AC_proj}, and S_{OC} are surface areas with a previous pea crop and another previous crop respectively, projected or actual, in hectares (Table 1), R_{PREV_PEAS} and R_{OC} are yields with a previous pea crop and another previous crop respectively, and $F_{PREV\_PEAS\_tDM}$ and F_{AC_tDM} are emissions factors per tonne of dry matter produced with a previous pea crop and another previous crop respectively.

APPENDIX II. DETAILS OF EMISSION ASSESSMENT CALCULATIONS FOR LIVESTOCK SUBSIDIES

Estimation of additional carbon storage as a result of the various CAP measures is mainly based on the (Pellerin et al., 2013a) and (Arrouays et al., 2002) studies.

a. *"Buffer strip" GAEC – grasslands*

Activity data: surface area of buffer strips for grasslands

0.25 Mha in 2014 with a rate of 60.4% for grasslands, i.e. 0.151 Mha of grass strips for grasslands (see appendix I.d).

Emission factors

Grass strips are treated in the same way as grasslands by Pellerin et al. (2013a), which is why additional storage is only possible if the plot was used for crops. Doses of inputs per hectare are taken from Agreste (2011), except for organic nitrogen inputs (Agreste, 2010a). One dose of phytosanitary product is estimated at 0.1kg of active substance per hectare according to Aubertot et al. (2005). Sources for emission factors per dose of input are the same as in appendix III.a. Emissions from animals and their waste are not considered (implicit assumption: for grazed grasslands, grass strips receive as much waste as the rest of the grassland and the stocking rate per hectare remains unchanged). Emissions per quantity produced are not estimated, due to the lack of an assumption regarding the quantity of grass produced in the absence of treatment of grass strips.

b. *"Management of grasslands" GAEC – grasslands*

"Soil and biomass carbon" reference scenario and emission factor

The reference scenario considered is a loss of grassland. The assumptions adopted concerning future use of lost grasslands are:

- that they are converted into three other uses (crops, forest and residential areas) on a pro rata basis according to conversions nationally;
- in the case of conversion to crops, half of surface areas are converted to forage maize and livestock become enclosed, the other half is converted to field crops and the herd ceases to exist.

The conversion of grasslands to forest, crops or residential areas causes changes to carbon stocks in the soil and in biomass (Table 7). The average conversion rates of grasslands (Table 7) have been calculated based on matrices of change of land use over the period 1992-2012 (CITEPA, 2014). Conversions into "other land" are not counted.

Table 7. Emission factor and conversion rate of grasslands into other uses

Land use conversion	Emission Factor ($tCO_2e/ha/yr$)	Conversion rate of grassland into other uses (2005-2012)
Grassland into forest	-5,00	10%
Grassland into cropland	3,252786762	77%
Grassland into residential areas	6,5306015	12%

Source: CITEPA (2014) and CITEPA (2013c)

Emission factors linked to usage

Except for the change in carbon stocks, the conversion of grassland will affect emissions, removing those associated with management of the grassland (fertilisation, emissions from herds, etc.) and replacing them with emissions from the new usage (e.g. fertilisation and emissions linked to herds in buildings in the event of conversion into forage maize). Emissions from the various uses of the soil are therefore calculated based on the following assumptions:

- grassland: an average stocking rate per hectare of 1.56 LSU (Agreste, 2010a), 60% of the time in grassland and 40% in buildings (CITEPA, 2013c). Emissions factors linked to herd emissions are taken from CITEPA (2013c) for parameters specific to France and the IPCC (2006) for those which CITEPA takes from the IPCC. Emissions linked to inputs and mechanisation come from the same sources as for crops (see Appendix III.a), except for organic inputs (Agreste, 2010a);
- forage maize: forage crops are assumed to support 1.9 LSU more per hectare than the herd stocking rate of the grassland they replace. This estimate is obtained from FADN data (2013), adjusted for costs of concentrates1. It does not vary significantly for sub-samples (e.g. Dairy farms only, farms self-sufficient in concentrates, etc.). Sources are identical to grasslands for emissions factors;
- crops: see Appendix I.b.
- forest: emissions linked to forestry operations are not counted. Emissions are therefore nil excluding the change in carbon sequestration;
- residential area: emissions are assumed to be nil, excluding the change in carbon sequestration. In practice, it is likely that construction on grasslands would be less dense, and therefore produce a higher level of emissions, than would have been the case in an existing residential area if the grassland had not been available for construction. This effect is difficult to quantify however.

Assessment per hectare of unconverted grassland

Emissions linked to each of these usages are summarised in appendix III. Table 8 sets out the assessment per hectare of unconverted grassland, weighted according to the proportion converted into each usage.

Table 8. Total GHGs per hectare of unconverted grassland as a result of the "management of grasslands" GAEC

	Emissions of N_2O from agricultural soils	Upstream GHG emissions	GHG emissions from livestock	Carbon storage	Total
In tCO2e/ha/yr	0,39	0,16	-0,52	2,80	2,83

[1] According to regression analysis: "stocking rate per hectare of MFA" = a + b*proportion of maize in the MFA + c*"amount of concentrates" + ε

Assessment per quantity of product (litre of milk/kg of meat)

For each litre of milk, an intensive maize system releases 45% more emissions than an essentially grassland-based system: 0.8 kgCO2e/l compared with 0.55 kgCO2e/l (Dollé et al., 2013). For suckler herds, an intensive system releases around 54% more emissions (Gac et al., 2010). However, it is difficult to carry out an assessment per quantity of product given that the type of product partially changes, since 50% of grasslands converted to crops are assumed to produce non-animal feed products.

Irrespective of previous estimates, since the GAEC did not prevent the loss of grasslands, it has no impact on the carbon footprint overall or by quantity of product.

c. "Maintenance of landscape features" GAEC – grasslands

Activity data: length of hedgerow

See section **Erreur ! Source du renvoi introuvable.**.

Emission factor

It is assumed that no enrichment agent (fertilisers or pesticides) are added to hedgerows. Emissions linked to fuel consumption are slightly higher than for grasslands, though negligible (Pellerin et al., 2013b). The emission factor linked to inputs is calculated based on average use of mineral fertilisers and pesticides on grasslands (see Appendix III.b).

A hectare of grasslands including hedgerows is assumed to contain 100 linear metres, taking up 2% of the surface area of the land (Pellerin et al., 2013b).

Estimation of GHG emissions avoided per hectare (surface area approach) and per quantity produced

The method is the same as for grass strips for crops and provides the results summarised in Table 9. Emissions per litre of milk and per hectare of MFA dedicated to dairy farming in a mainly grassland-based farm are taken from Guyomard (2013). Emissions per litre of milk are also roughly equivalent to Dollé et al. (2013).

Table 9. GHG emissions avoided by the planting of hedgerows for grasslands

	Avoided emissions of N_2O from agricultural soils	Upstream GHG emissions avoided	GHG emissions from livestock	Additional carbon storage	Total
In tCO2e/ha[1]/yr	-0,01	-0,01	-0,10	-0,92	-1,03
Total (MtCO2e/yr)	0,00	0,00	0,00	0,00	0,00
Per product quantity	-26 % per litre of milk. Reduction in yield of 2 %.				

[1] On a basis of 100 linear metres of hedgerow per hectare according to Pellerin et al. (2013).

d. "Minimum land management" GAEC – grasslands

"Soil and biomass carbon" reference scenario and emission factor

The reference scenario considered is a conversion from grassland to forest. The conversion of crops to forest causes changes to carbon stocks in the soil and in biomass. The emission factor linked to these changes is taken directly from the national inventory (CITEPA, 2013c).

Emission factors linked to usage

Excluding the change in carbon stocks, the conversion of grassland will affect emissions, removing those associated with management of the grassland (fertilisation, emissions from herds, etc.) and replacing them with emissions from the new usage. Emissions from the various uses of the soil are therefore calculated based on the following assumptions:

- grassland: see appendix II.b and appendix III.b ;
- forest: emissions linked to forestry operations are not counted. Emissions are therefore nil excluding the change in carbon sequestration.

Assessment per hectare of unconverted grassland

Table 10 sets out the assessment per hectare of unconverted grassland, weighted according to the proportion converted into each usage.

Table 10. Total GHGs per hectare of unconverted grassland as a result of the "minimum land management" GAEC

	Emissions of N_2O from agricultural soils	Upstream GHG emissions	GHG emissions from livestock	Carbon storage	Total
In tCO2e/ha/yr	0,47	0,30	4,96	5,00	10,72

Since the measure is deemed to be inefficient (see section **Erreur ! Source du renvoi introuvable.**), its total effect is nil.

Assessment per quantity of product (litre of milk/kg of meat)

The assessment per quantity of product is difficult to calculate due to the transition from an agricultural product to a forestry product.

e. *Pillar 1: "support for organic farming" – livestock*

Activity data: forage areas for organic farming

Changes in organic forage areas are calculated based on changes in the total organic surface area, assuming no variation occurs in the proportion of forage areas over the period so that they remain equal to their proportion in 2013, i.e. 65%. Changes in organic surface areas do not present any significant trends between 2002 and 2006 ($p = 0.16$). We have therefore taken the average surface area for the period 2002-2006, 0.35 Mha, as the reference surface area, compared with an average of 0.51 Mha for the period 2007-2012.

Emission factor

Van der Werf et al. (2009) estimate emissions from dairy farms operated as organic farms and conventional farms, without counting carbon sequestration by grasslands. To make these results consistent with the rest of the report, we have removed this sequestration from the organic farming emissions. To do this, Van der Werf et al. (2009) provide the proportion of maize in the main forage area, to which we have added the surface area considered necessary by Van der Werf et al. (2009) for the production of concentrates consumed by the farms: 41% maize for conventional farming compared with 10% for organic farming. The difference (31%) is assumed to have been converted from maize to grassland during the conversion to organic farming. The emissions factor corresponding to this conversion is taken from CITEPA (2014), in line with the rest of the study.

Table 11 presents the different stages and the various components of the calculation.

Table 11. Key figures for conventional and organic livestock farming

	Emission factor (in tCO2e/ha of MFA/yr) excluding LULUCF	Emission factor (in tCO2e/ha of occupied land, including concentrates production/yr) excluding LULUCF	Share of maize in the corrected MFA for concentrates	Storage linked to the conversion of maize into grassland (tCO2/ha of MFA/yr)	Emission factor (in tCO2e/ha de MFA/yr) including LULUCF
Conventional farming	5,24	6,27	0,41	0	5,24
Organic farming	4,68	4,89	0,10	1,02	3,66
	Dairy productivity (standardized litre/ha MFA/yr)	Dairy productivity (standardized litre/ha of occupied land (including concentrates production) /yr)	Emission factor (in tCO2e/ha of occupied land, including concentrates production/yr) including LULUCF	Emission factor exluding LULUCF (in tCO2e/ton of milk standardized with protein and fat/yr)	Emission factor including LULUCF (in tCO2e/ton of milk standardized with protein and fat/yr)
Conventional farming	7197	6018	6,27	1,08	1,08
Organic farming	4416	4230	3,87	1,04	0,82

Source: CDC Climat Research based on Van der Werf (2009).

Estimation of GHG emissions avoided per quantity produced by organic farming

See Table 11. The fall in yields measured by Van der Werf et al. (2009) and used in this report (-30% per hectare of MFA, -28% per cow) are also comparable to those used in other studies summarised by Guyomard (2013).

f. Pillar 2: "agri-environmental grassland premium"

Reference scenario

The reference scenario considered is a loss of grassland. The assumptions adopted concerning future use of lost grasslands are:

- that they are converted into forage maize, since the AEM provides compensation for loss of livestock farming income compared with continued agricultural use;
- despite conversion to crops, the herd is maintained. We assume that the ploughing of grasslands feeds 1.9 LSU more per hectare (see appendix II.b).

Assessment per hectare (of "unconverted" grassland)

The assessment per hectare of unconverted grassland is calculated using the same procedure as for the "management of grasslands" GAEC (see appendix II.h) with two exceptions:

- the "forage maize" alternative is considered to represent 100% of the surface areas in question, compared with 77% for the GAEC;
- the stocking rate per hectare is assumed to be 1.4 LSU/ha compared with the French average for grasslands of 1.56 LSU/ha for the GAEC.

Surface area subject to a PHAE contract

The surface area of grassland contracted to this AEM is 4 Mha. (DG Agriculture, 2011)

Additionality

Chabé-Ferret and Subervie (2009) consider that farms which have registered for the PHAE have reduced their non-grassland surface area by 2 points more than those which have not registered. The surface area of preserved grassland is therefore estimated by:

$$s_{pc} = s_{ce\_PHAE} \times \alpha = \frac{s_{p\_PHAE}}{1 - p_{crop\_PHAE}} \times p_{crop\_PHAE} \times \alpha$$

Where s_{pc} is the surface area of grassland preserved by the AEM, s_{ce_PHAE} is the surface area of crops avoided by the AEM, s_{p_PHAE} is the surface area of grassland registered with the PHAE (4 Mha), p_{crop_PHAE} is the proportion of crops on farms which have registered for the PHAE and α is the degree of additionality (0.02).

Table 12. Estimation of GHG emissions avoided by the "agri-environmental grassland premium" AEM

Mitigation potential	Emissions of N_2O from agricultural soils	Upstream GHG emissions	GHG emissions from livestock	Carbon storage	Total
In tCO2e per hectare of conserved grassland	-0,73	-0,09	-6,48	-3,25	-10,55
Total (MtCO2e)	-0,008	-0,001	-0,07	-0,03	-0,11
Per product quantity	For each litre of milk, a low impact grass system releases 31% less emissions than a more intensive maize system: : 0.8 kgCO2e/l compared with 0.55 kgCO2e/l (Dollé et al., 2013). For suckler herds, an extensive system releases around 35% emissions less (Gac et al., 2010).				

Source: CDC Climat Research based on data from the IPCC (2006) and CITEPA (2013a).

g. *Pillar 2: "low-input forage system"* (Système Fourrager Econome en Intrants – *SFEI)*

Le Rohellec et al. (2010) provide a detailed comparison of practices and yields obtained by farmers registered for the SFEI AEM compared with comparable farms.

Reference scenario

The reference scenario considered is the same as for the PHAE AEM (section f), i.e. a loss of grassland. The assumptions adopted concerning future use of lost grasslands are:

- that they are converted to crops, since the AEM provides compensation for loss of livestock farming income compared with continued agricultural use. The choice of crop will no doubt be maize since 37% of equivalent farms in western France grew maize in 2008 (Le Rohellec et al., 2010) although the limit in the specifications is 18%.
- despite conversion to crops, the herd is maintained. Le Rohellec et al. (2010) assume a slightly higher stocking rate per hectare of forage area for the non-SFEI "reference" farmers: 1.8 LSU/ha compared with 1.4 LSU/ha for SFEI.

Surface area subject to an SFEI contract

The physical surface area contracted to this AEM is 0.04 Mha. (DG Agriculture, 2011). We assume that this only concerns the forage area, considering that in any case it represents 85% of the UAL of farms registered for the scheme.

Additionality

The SFEI was not studied by Chabé-Ferret and Subervie (2012, 2009). The SFEI's specifications resemble a combination of the specifications for three other AEMs studied by Chabé-Ferret and Subervie (2009): AEM 8 "Modifying phytosanitary treatments", AEM 9 "Modifying fertilisation" and AEM 20 "Extensive management of grasslands". It may be considered that the most restrictive specifications will determine the degree of additionality. Consequently, the α applied is the highest α of the three AEMs, i.e. 0.32 in AEM 9.

Assessment per hectare (of "unconverted" grassland)

Data concerning fertilisation, rotation and stocking rates (Table 13) are taken from Le Rohellec et al. (2010). For farmers registered on the SFEI AEM, the values selected are "stable" values, i.e. those of "original signatories" who have achieved stability after a transition phase. These are compared with national averages for grasslands and maize (Agreste, 2011, 2010a). Since detailed practices of farmers registered for the AEM are not available for phytosanitary products, we have corrected the values taken from Agreste (2011, 2010a) according to the ration between the two Treatment Frequency Indices: $FTI_{AEM}/FTI_{reference}$. The emissions factors applied for grasslands and maize are the same as for the PHAE AEM (section f).

Table 13. Cropping practices of farms subject to an SFEI contract

	Farmers registered for the SFEI AEM	"Reference" non-SFEI farmers
Mineral nitrogen kgN/ha of grassland	2	27
Mineral nitrogen kgN/ha of maize	2	64
Organic nitrogen kgN/ha of grassland	50	28
Organic nitrogen kgN/ha of maize	61	124
Grassland TFI	0.05	0.021
Maize TFI	0.88	1.66
Proportion of grasslands in the forage area	91%	63%
Stocking rate (LSU/ha of forage area)	1.4	1.8

Source: (Agreste, 2011, 2010a; Le Rohellec et al., 2010)

Two mitigation effects are therefore combined: preservation of grasslands – as for the PHAE AEM – and lower intensity of fertilisation and phytosanitary treatments per hectare of maize and grassland for registered farms compared with the national average due to the specifications. The summary per hectare of forage area registered with the AEM is provided in Table 14.

Assessment per quantity of product (litre of milk)

Since two-thirds of the farms' activity is milk production, only the estimate per litre of milk has been carried out. Le Rohellec et al. (2010) compare milk yields of original signatories of the AEM (5,216 l/cow/year) and "reference" dairy farmers (6,811 l/cow/year). Application of the above-mentioned activity data and emission factors produces a result of 0.81 kgCO2e/l for reference farms and 0.77 kgCO2e/l for farms registered with the AEM. This is roughly comparable to the values arrived at by Dollé et al. (2013) although the difference between the two systems is much lower than that reported by Dollé et al. (2013) when comparing "optimised" and "non-optimised" farms. This discrepancy is apparently due to the denominator since milk production is almost identical between the two types of farms compared by Dollé et al. (2013).

Table 14. Mitigation potential per hectare of forage area registered with the SFEI AEM

Mitigation potential	Emissions of N_2O from agricultural soils	Upstream GHG emissions	GHG emissions from livestock	Carbon storage	Total
In tCO2e per hectare of conserved grassland	-0,31	-0,22	-3,89	-3,25	-7,67
Total (MtCO2e)	-0,00014	-0,00010	-0,0018	-0,0015	-0,0035
Per product quantity	For each litre of milk, the farmers who subscribe to SFEI AEM release 15 % emissions less. Fall in yield of : -40 % per hectare of MFA.				

h. Pillar 1: “support for legumes" – grasslands

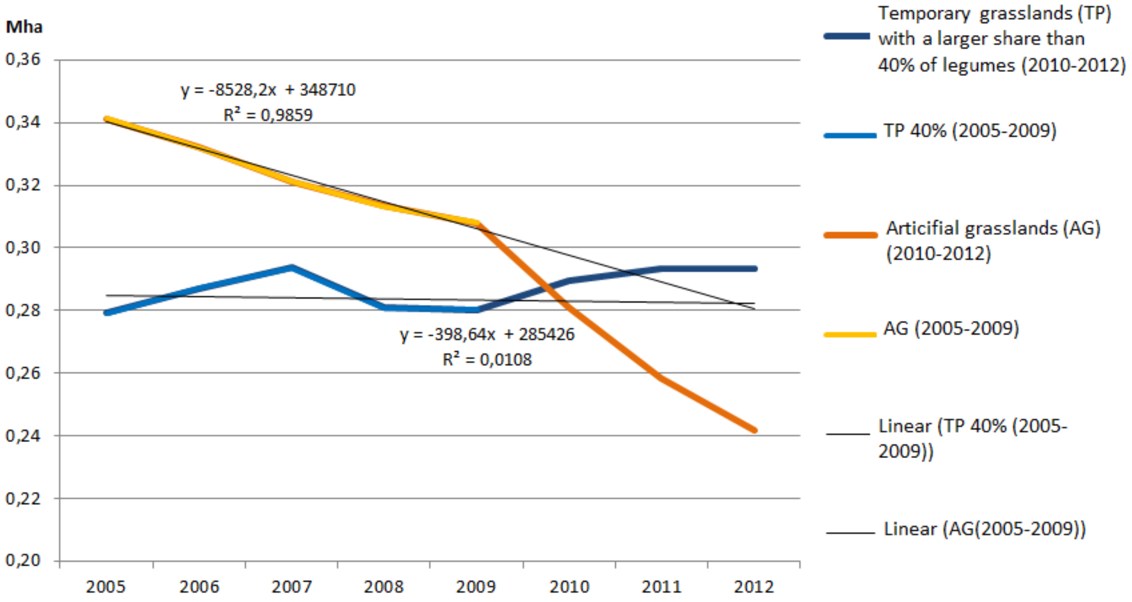
Support for forage legumes on grasslands

Activity data: surface area of forage legumes (artificial grasslands) and temporary grasslands

Pellerin et al. (2013a) indicate that the reduction in nitrogen fertilisation on grasslands is effective when the proportion of legumes is above 40%. Yet the proportion of permanent grasslands (PG) planted with more than 40% legumes represents 0.05% of the total surface area farmed. Only temporary grasslands (TG) and artificial grasslands (AG) are therefore included in the calculation. According to Pellerin et al. (2013a) and the "cropping practices" study (Agreste, 2010a), the percentage of temporary grassland with more than 40% coverage in legumes is 10.21%. This percentage is assumed to be constant over the study period (2005-2012). Furthermore, Agreste (2014) defines artificial grassland as grassland which is still more than 80% sown with one or more types of forage legumes. Most forage legumes therefore fall into this category.

CGDD (2013) identifies a declarative bias between temporary grasslands and permanent grasslands, with the declared surface area of permanent grasslands falling sharply by 260,000 ha between 2009 and 2010, while the declared surface area of temporary grassland rose by 355,000 ha. This bias is probably linked to the introduction of the "management of grasslands" GAEC which is more restrictive on the sale or ploughing of permanent grassland than temporary grassland. This is rectified here by adding the fall recorded in permanent grasslands between 2009 to 2010 to the surface area of permanent grasslands between 2010 and 2012, and removing this same amount from the surface area of temporary grassland between 2010 and 2012.

Figure 3. Change in surface area of temporary grasslands whose proportion of legumes is above 40% and the surface area of artificial grasslands



Source: CDC Climat Research based on data from (Agreste, 2013a)

The surface area of artificial grassland fell significantly (P = 0.0007) and steadily over the period 2005-2009. Linear extrapolation of this trend for the period 2010-2012 is therefore our BAU scenario. Since the establishment of coupled support under Pillar 1 in 2010, the decrease in surface areas accelerated, contrary to the expected effects of the measure (Figure 3). The effect of the measure is therefore considered to be nil for the surface area of legumes on artificial grasslands.

The surface areas of temporary grasslands do not present any significant trends between 2005 and 2009 (P = 0.87). The BAU scenario considered is therefore the average for temporary prairies comprising more than 40% legumes for the period 2005-2009 (Table 15), i.e. 0.284 Mha. The average annual surface area recorded by the annual agricultural statistics agency (SAA) (Agreste, 2013d) over the period 2010-2012 was 0.292 Mha (Table 15).

Table 15. Change in the surface area of grasslands and comparison with projection

	2005	2006	2007	2008	2009	2010	2011	2012
Surface area of temporary grasslands with more than 40% coverage in legumes (Mha)	0.279	0.287	0.294	0.281	0.280	0.289	0.293	0.293
Artificial grasslands (Mha)	0.341	0.332	0.321	0.313	0.308	0.281	0.258	0.242

Source: Agreste (2013d)

Emission factor: unitary mitigation of forage legumes

The difference in the emissions reductions between the two sub-actions (support for protein crops (appendix I.g) and support for forage legumes) can be explained by the difference between the units used to express the emission factor. For field crops, the reduction in GHG emissions is estimated per hectare of legumes planted while for grasslands it is estimated per hectare of grassland, which is generally not exclusively made up of legumes. Furthermore, fertilisation is generally less for grasslands than for crops.

Table 16. Value of direct, indirect and upstream emissions of GHG avoided

	N_2O emissions (in tCO_2e/ha/year)	Direct CO_2 emissions (in tCO_2e/ha/year)	Upstream GHG emissions (in tCO_2e/ha/year)
For legumes in grasslands (per ha of grassland)	0.170	0.00136	0.156

Source: Pellerin et al. (2013a)

Estimation of N_2O emissions avoided as a result of support to legumes

As a result of support for planting legumes on grassland: (0.292 – 0.284) x (-0.170)= - 0.001 $MtCO_2e$/year

Estimation of direct GHG emissions avoided as a result of reduced use of fuel on the farm

(0.292 – 0.284) x (-0.00136) = - 0.01 x 10^{-3} $MtCO_2e$/year

Estimation of induced GHG emissions avoided as a result of reduced use of fertiliser

Emissions factors are taken from Pellerin et al. (2013).

(0.292 – 0.284) x (0.156)= - 0.001 $MtCO_2e$/year

i. Pillar 1: "support for dairy farming in mountainous regions"

Reference scenario

The reference scenario considered is a loss of herds and associated grassland. The assumption adopted concerning future use of lost grasslands in mountainous regions is:

- that they are converted to forestry use. It is assumed in this case that land and altitude difficulties present an obstacle to conversion to crops or residential use.

Activity data: surface area of mountain dairy farms' grasslands

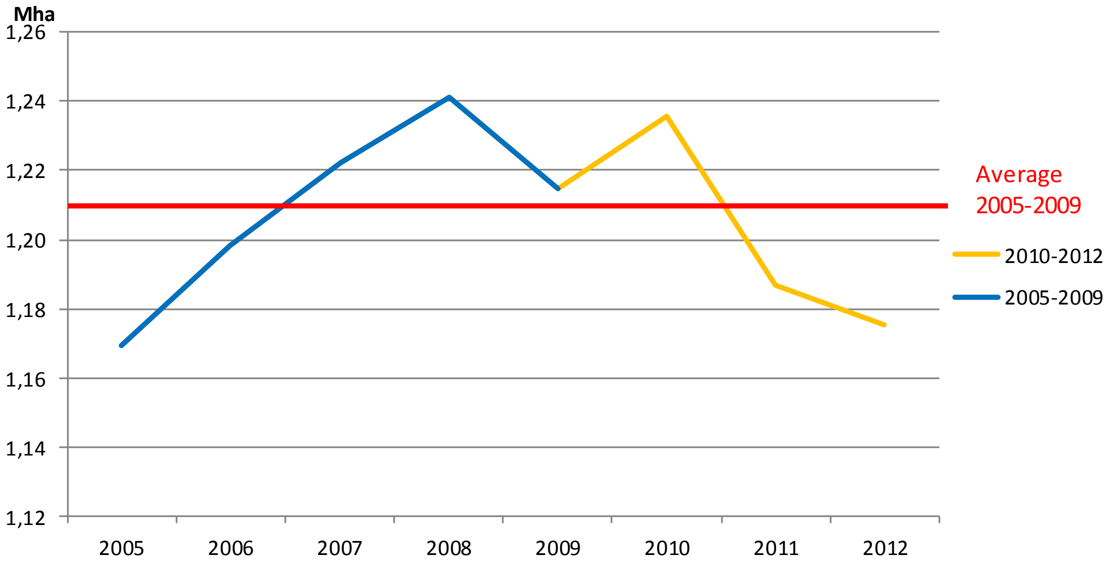
Activity data (surface area of mountain dairy farms' temporary and permanent grasslands) are not directly available. They have been reconstructed based on the Farm Accountancy Data Network survey (FADN France and Agreste, 2013), adjusted annually for each region to ensure coherence with the annual agricultural statistics (Agreste, 2013d) used elsewhere:

$$S_{grassland\_milk\_mountain\_it} = S_{grassland\_milk\_mountain\_FADN\_it} \times \frac{S_{grassland\_SAA\_it}}{S_{grassland\_RICA\_it}}$$

Where $S_{grassland\_milk\_mountain\_it}$ is the activity data sought for region i in year t, $S_{grassland\_milk\_mountain\_FADN\_it}$ is the surface area of mountain dairy farms' grasslands provided by FADN for region i in year t, $S_{grassland\_FADN\_it}$ is the total surface area of grassland provided by the FADN for region i in year t and $S_{grassland\_SAA\_it}$ is the total surface area of grassland given by SAA for region i in year t.

The growth in $S_{grassland\_milk\_mountain\_it}$ during the period 2005-2009 is not significant (P = 0.12). The measure is not deemed to be effective when the average for $S_{grassland\_milk\_mountain\_it}$ during the period 2010-2012 (1.20 Mha) is less than the average for 2005-2009 (1.21 Mha).

Figure 4. Change in the surface area of mountain dairy farms' grasslands (temporary and permanent)



Source: CDC Climat Research based on data from the FADN (2013) and Agreste (2013d)

Assessment per hectare (of "unconverted" grassland)

According to (Agreste, 2013e), the average stocking rate of dairy farms in disadvantaged mountainous areas is 1 LSU/ha. Otherwise, the sources and methods for calculating emissions factors are the same as for the "grasslands" GAEC, replacing weighted averages for the herd measured in LSU of each type of animal with emissions factors specific to dairy cows (Table 17).

Table 17. Support for dairy farming in mountainous regions and GHG emissions

Mitigation potential	Emissions of N_2O from agricultural soils	Upstream GHG emissions	GHG emissions from livestock	Carbon storage	Total
In tCO2e per hectare of conserved grassland	0,47	0,30	5,23	5,00	11,00
Total (MtCO2e/an)	0 : the average of dairy farms' grasslands (2010-2012) is below the average before the measure (2005-2009).				
Per product quantity	Cannot be calculated : the counterfactual scenario is the absence of milk production				

Source: CDC Climat Research

j. Compensatory allowances for natural disadvantages (Indemnités compensatoires d'handicaps naturels – ICHN)

Similar to support for dairy farming in mountainous regions but not quantified since it did not experience any change since 2001.

k. Pillar 1: decoupling of support to beef cattle

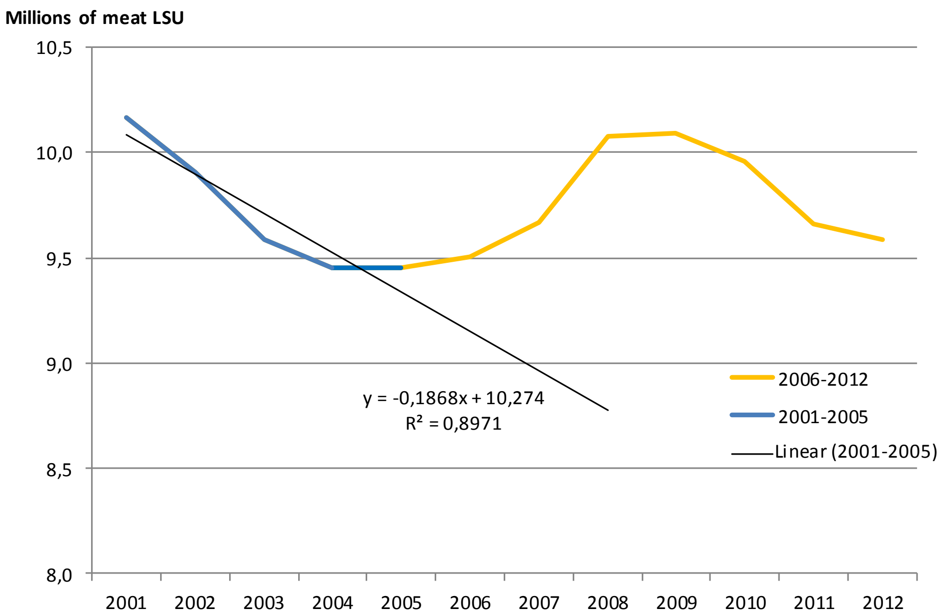
Reference scenario

The reference scenario considered is maintenance of the "beef cattle" livestock – suckler cows and associated young beef cattle – in cases where partial decoupling of this measure may lead to a reduction in the size of the herd. Changes in the forage area are not considered here since the decoupled support maintains support for the "livestock" element of farming activity, although this support is no longer dependent on productivity.

Activity data: "beef cattle" livestock

Changes to the "beef cattle" livestock as defined by CITEPA – i.e. all beef cattle excluding dairy cows – present a significant trend (P = 0.01) over the period 2001-2005 (Figure 5).

Figure 5. Change in suckler cow livestock between 2001 and 2012



Source: CDC Climat Research based on data from Eurostat

The BAU scenario is therefore the average projected values for the period 2006-2012 based on linear regression for 2001-2005. This gives a figure of 8.6 million LSU compared with 9.8 million reported by Eurostat. The measure is therefore deemed to be ineffective.

Assessment per non-produced LSU

The assessment by non-produced LSU following decoupling is carried out using the same emissions factors and assumptions as for the "grasslands" GAEC for livestock emissions, replacing weighted averages for the herd measured in LSU of each type of animal with emissions factors specific to "beef cattle" (Table 18). Emissions linked to management of forage areas are considered to be constant (see above).

Table 18. Partial decoupling of support to beef cattle

Mitigation potential	Emissions of N_2O from agricultural soils	Upstream GHG emissions	GHG emissions from livestock	Carbon storage	Total
In tCO2e by meat LSU non produced	0,00	0,00	-3,10	0,00	-3,10
Total (MtCO2e)	0,00	0,00	0,00	0,00	0,00
Per product quantity	This is a decline in production. There is no obvious impact on emission per kilogram of carcass. The slight incentive to extensification of fodder surfaces supplied by partial decoupling is neglected here				

Source: CDC Climat Research.

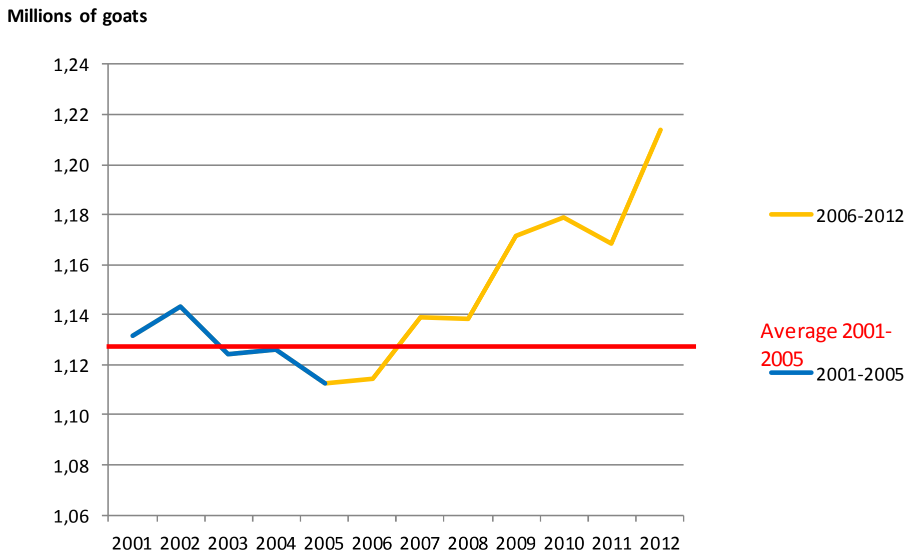
Assessment per quantity of product (kg of meat or litre of milk per hectare of MFA)

In principle, decoupling of support provides an incentive for pastures rather than forage crops, since support is no longer dependent on stocking rate per hectare, which increases with the proportion of forage crops in the MFA. This is particularly clear from the simulations carried out using the AROPAj model (Galko, 2007). In line with the results referred to in appendix II.f, we could therefore expect a fall in emissions per quantity of product. However, since the surface area of grassland fell steadily following decoupling, while at the same time there was an increase in yield per animal (litre of milk per cow of kg of meat per LSU) which generally indicates a fall in emissions per quantity of product, the assessment of decoupling per quantity of product is not estimated.

I. Pillar 1: decoupling of support to goats

The methods and emissions factors are the same as for "beef cattle", replacing emissions factors specific to suckler beef livestock with those specific to goats (**Erreur ! Source du renvoi introuvable.**). The change in the number of goats does not reveal a significant trend (P = 0.12) over the period 2001-2005 (Figure 6). Furthermore, the average for 2006-2012 is higher than the average for 2001-2005. The measure is therefore deemed to be ineffective.

Figure 6. Change in goat livestock between 2001 and 2012



Source: CDC Climat Research based on data from Eurostat

Table 19. Partial decoupling of support to goats

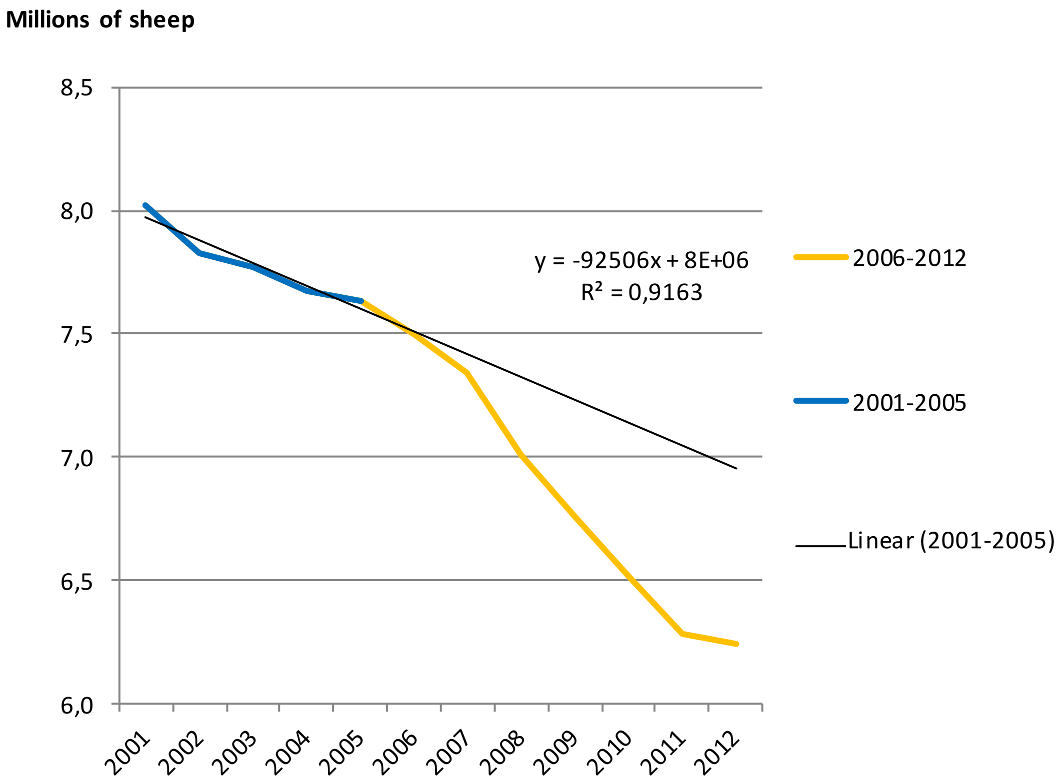
Mitigation potential	Emissions of N_2O from agricultural soils	Upstream GHG emissions	GHG emissions from livestock	Carbon storage	Total
In tCO2e per LSU non produced	0,00	0,00	-2,25	0,00	-2,25
Total (MtCO2e)	0,00	0,00	0,00	0,00	0,00
Per product quantity	This is a decline in production. There is no obvious impact on emission per kilogram of carcass. The slight incentive to extensification of fodder surfaces supplied by partial decoupling is neglected here				

Source: see appendix II.I.

m. Pillar 1: decoupling of support to sheep

The methods and emissions factors are the same as for "beef cattle", replacing emissions factors specific to suckler beef livestock with those specific to sheep. The change in the number of sheep reveals a significant trend (P = 0.01) over the period 2001-2005 (Figure 7). Furthermore, the average for 2006-2012 is lower than the projected average following linear regression for 2001-2005. The measure is therefore deemed to be effective.

Figure 7. Change in sheep livestock between 2001 and 2012



Source: CDC Climat Research based on data from Eurostat

APPENDIX III. GREENHOUSE GAS ASSESSMENT OF SOME LAND USES

a. Average field crops

Grande culture moyenne		FE (tCO2e/kg substance active)	Source	Dose (kg substance active/ha)	Source	Emissions (tCO2e/ha)
Production engrais	N	0,0053	ADEME (2010)	138	Pellerin et al. (2013)	0,73
Production engrais	P	0,0006	ADEME (2010)	27,8	EPC 2011	0,02
Production engrais	K	0,0004	ADEME (2010)	26,5	EPC 2011	0,01
Production phytos	Herbicides	0,0090	ADEME (2010)	0,27	EPC 2011, Aubertot et al (2005)	0,002
Production phytos	Fongicides	0,0061	ADEME (2010)	0,17		0,001
Production phytos	Insecticides	0,0253	ADEME (2010)	0,06		0,001
Production phytos	Regulateurs	0,0085	ADEME (2010)	0,03		0,0003
Production phytos	Molluscides	0,0090	ADEME (2010)	0,01		0,0001
Champ	engrais N minéral	0,0057	tCO2e/kgN, Pellerin et al. (2013)	138	Pellerin et al. (2013)	0,79
Champ	apports N organiques	0,0067	tCO2e/kgN, IPCC 2006 et CITEPA 2013	33,4	EPC 2011	0,22
Mécanisation (construction engins + carburant)		0,0258	tCO2/ha, Bilan Carbone v6.1	1		0,03
Emissions amont (y compris carburant)						0,79
Emissions N2O au champs (tCO2e/ha)						1,01
Emissions GES totales (tCO2e/ha)						1,81
Emissions GES totales (tCO2e/tMS)						0,28
Production AC Blé/orge (CGS	6,42					

b. *Average grassland*

Prairie		FE (tCO2e/kg substance active)	Source	Dose (kg substance active/ha)	Source	Emissions (tCO2e/ha)						Source
						Chargement moyen (1,56 UGB/ha)	Chargement PHAE (1,4 UGB/ha)	Orientation lait, chargement montagne (1,0 UGB/ha)	Orientation viande (1,0 UGB/ha)	Caprins (1,0 UGB/ha)	Ovins (1,0 UGB/ha)	
						1,56	1,4	1	1	1	1	
Production engrais	N	0,0053	ADEME (2010)	50	Pellerin et al. (2013)	0,27	0,27	0,27	0,27	0,27	0,27	
Production engrais	P	0,0006	ADEME (2010)	6,9	EPC 2011	0,004	0,00	0,00	0,00	0,00	0,00	
Production engrais	K	0,0004	ADEME (2010)	10,1	EPC 2011	0,004	0,00	0,00	0,00	0,00	0,00	
Production phytos	Herbicides	0,0090	ADEME (2010)	0,01	EPC 2011, Aubertot et al (2005)	0,000	0,00	0,00	0,00	0,00	0,00	
Production phytos	Fongicides	0,0061	ADEME (2010)	0,00		0,000	0,00	0,00	0,00	0,00	0,00	
Production phytos	Insecticides	0,0253	ADEME (2010)	0,00		0,000	0,00	0,00	0,00	0,00	0,00	
Production phytos	Regulateurs	0,0085	ADEME (2010)	0,00		0,000	0,00	0,00	0,00	0,00	0,00	
Production phytos	Molluscides	0,0090	ADEME (2010)	0,00		0,000	0,00	0,00	0,00	0,00	0,00	
Champ	engrais N minéral	0,006	tCO2e/kgN, Pellerin et al. (2013)	50	Pellerin et al. (2013)	0,29	0,29	0,29	0,29	0,29	0,29	
Champ	épandage N organiques	0,007	tCO2e/kgN, IPCC 2006 et CITEPA 2013	27,6	EPC 2011	0,18	0,18	0,18	0,18	0,18	0,18	
Champ	N2O déjections en prairie					0,68	0,61	0,42	0,37	0,04	0,38	IPCC 2006, CITEPA 2013
Champ	N2O déjections en bâtiment "l'hiver"					0,11	0,09	0,05	0,07	0,20	0,07	IPCC 2006, CITEPA 2013
Champ	CH4 déjection en prairie					0,03	0,03	0,02	0,01	0,00	0,02	IPCC 2006, CITEPA 2013
Champ	CH4 déjection en bâtiment l'hiver					1,03	0,92	1,71	0,64	0,03	0,02	IPCC 2006, CITEPA 2013
Champ	CH4 entérique					3,11	2,79	3,02	2,02	1,97	1,58	IPCC 2006, CITEPA 2013
Mécanisation (construction engins + carbura		0,0257786	tCO2/ha, Bilan Carbone v6.1	1		0,03	0,03	0,03	0,03	0,03	0,03	
Emissions amont (y compris carburant)						0,30	0,30	0,30	0,30	0,30	0,30	
Emissions N2O au champ/bâtiment (tCO2e/ha)						1,26	1,18	0,94	0,91	0,71	0,92	
Emissions N2O au champ hors cheptel (tCO2e/ha)						0,47	0,47	0,47	0,47	0,47	0,47	
Emissions CH4 au champ/bâtiment (tCO2e/ha)						4,17	3,74	4,75	2,67	2,01	1,62	
Emissions GES totales (tCO2e/ha)						5,73	5,22	6,00	3,88	3,02	2,84	
Emissions GES totales hors cheptel (tCO2e/ha)						0,77	0,77	0,77	0,77	0,77	0,77	
Emissions GES totales (tCO2e/litre de lait)						0,00055						Dollé et al 2013
Emissions GES totales (tCO2e/100 kg viande vive)						0,725						Gaec 2010

c. *Forage maize*

Maïs fourrager et chargement moyen d'une prairie passé en bâtiment l'été		FE (tCO2e/kg substance active)	Source	Dose (kg substance active/ha)	Source	Emissions (tCO2e/ha) Chargement moyen (1,56 UGB/ha)	 Chargement PHAE (1,4 UGB/ha)	 1,9 + chargement moyen (3,5 UGB/ha)	 1,9 + chargement PHAE (3,3 UGB/ha)	Source
						1,56	1,4	3,46	3,3	
Production engrais	N	0,0053	ADEME (2010)	63,7	Pellerin et al. (2013)	0,34	0,34	0,34	0,34	
Production engrais	P	0,0006	ADEME (2010)	25,4	EPC 2011	0,014	0,01	0,01	0,01	
Production engrais	K	0,0004	ADEME (2010)	21,5	EPC 2011	0,010	0,01	0,01	0,01	
Production phytos	Herbicides	0,0090	ADEME (2010)	0,30	EPC 2011, Aubertot et al (2005)	0,003	0,00	0,00	0,00	
Production phytos	Fongicides	0,0061	ADEME (2010)	0,00		0,000	0,00	0,00	0,00	
Production phytos	Insecticides	0,0253	ADEME (2010)	0,01		0,000	0,00	0,00	0,00	
Production phytos	Regulateurs	0,0085	ADEME (2010)	0,00		0,000	0,00	0,00	0,00	
Production phytos	Molluscides	0,0090	ADEME (2010)	0,00		0,000	0,00	0,00	0,00	
Champ	engrais N minéral	0,006	tCO2e/kgN, Pellerin et al. (2013)	63,7	Pellerin et al. (2013)	0,37	0,37	0,37	0,37	
Champ	épandage N organiques	0,007	tCO2e/kgN, IPCC 2006 et CITEPA 2013	124,4	EPC 2011	0,83	0,83	0,83	0,83	
Champ	N2O déjections en bâtiment "toute l'année"					0,19	0,17	0,42	0,40	IPCC 2006, CITEPA 2013
Champ	CH4 déjection en bâtiment "toute l'année"					1,87	1,67	4,14	3,95	IPCC 2006, CITEPA 2015
Champ	CH4 entérique					3,11	2,79	6,90	6,58	IPCC 2006, CITEPA 2016
Mécanisation (construction engins + carburant)		0,0257786	tCO2/ha, Bilan Carbone v6.1	1		0,03	0,03	0,03	0,03	
Emissions amont (y compris carburant)						0,39	0,39	0,39	0,39	
Emissions N2O au champ/bâtiment (tCO2e/ha)						1,39	1,37	1,62	1,60	
Emissions N2O au champ hors cheptel (tCO2e/ha)						1,20	1,20	1,20	1,20	
Emissions CH4 au champ/bâtiment (tCO2e/ha)						4,98	4,47	11,04	10,52	
Emissions GES totales (tCO2e/ha)						6,75	6,22	13,05	12,52	
Emissions GES totales hors cheptel (tCO2e/ha)						1,59	1,59	1,59	1,59	
Emissions GES totales (tCO2e/litre de lait)						0,0008	0,0008	0,0008	0,0008	Dollé et al 2013
Emissions GES totales (tCO2e/100 kg viande vive)						1,12	1,12	1,12	1,12	Gaec 2010

d. Grassland registered for the "SFEI" AEM and its counterfactual

Prairie SFEI et référence SFEI		FE (tCO2e/kg substance active)	Source	Dose "anciens signataires"	Dose moyenne référence (kg QSA/ha, cf EPC 2011)	Source	Emissions (tCO2e/ha) SFEI (1,4 UGB/haSFP) 1,4	Référence pour 1,4 UGB/haSFP 1,4	Référence pour 1,8 1,8			Source
Production engrais	N	0,0053	ADEME (2010)	2	26,9	FE : Pellerin et al. (2013) Dose : Le Rohellec (2010)	0,01	0,14	0,14			
Production engrais	P	0,0006	ADEME (2010)	3	6,9	idem	0,002	0,004	0,004			
Production engrais	K	0,0004	ADEME (2010)	5	10,1	idem	0,002	0,004	0,004			
Production phytos	Herbicides	0,0090	ADEME (2010)	0,00	0,008		0,000	0,000	0,000			
Production phytos	Fongicides	0,0061	ADEME (2010)	0	0,000	EPC 2011,	0,000	0,000	0,000			
Production phytos	Insecticides	0,0253	ADEME (2010)	0	0,000	Aubertot et al	0,000	0,000	0,000			
Production phytos	Regulateurs	0,0085	ADEME (2010)	0	0,000	(2005)	0,000	0,000	0,000			
Production phytos	Molluscides	0,0090	ADEME (2010)	0	0,000		0,000	0,000	0,000			
Champ	engrais N minéral	0,006	tCO2e/kgN, Pellerin et al. (2013)	2	26,9	FE : Pellerin et al. (2013) Dose : Le Rohellec (2010)	0,01	0,15	0,15			
Champ	épandage N organiques	0,007	tCO2e/kgN, IPCC 2006 et CITEPA 2013	50	27,6	idem	0,33	0,18	0,18			
Champ	N2O déjections en prairie						0,61	0,61	0,79			IPCC 2006, CITEPA 2013
Champ	N2O déjections en bâtiment "l'hiver"						0,09	0,09	0,12			IPCC 2006, CITEPA 2013
Champ	CH4 déjection en prairie						0,03	0,03	0,03			IPCC 2006, CITEPA 2013
Champ	CH4 déjection en bâtiment l'hiver						0,92	0,92	1,19			IPCC 2006, CITEPA 2013
Champ	CH4 entérique						2,79	2,79	3,59			IPCC 2006, CITEPA 2013
Mécanisation (construction engins + carburant)		0,026	tCO2/ha, Bilan Carbone v6.1	1			0,03	0,03	0,03			
Emissions amont (y compris carburant)							0,04	0,18	0,18			
Emissions N2O au champ/bâtiment (tCO2e/ha)							1,05	1,05	1,25			
Emissions N2O au champ hors cheptel (tCO2e/ha)							0,35	0,34	0,34			
Emissions CH4 au champ/bâtiment (tCO2e/ha)							3,74	3,74	4,81			
Emissions GES totales (tCO2e/ha)							4,83	4,96	6,23			
Emissions GES totales hors cheptel (tCO2e/ha)							0,39	0,52	0,52			
Emissions GES totales (tCO2e/litre de lait)												
Emissions GES totales (tCO2e/100 kg viande vive)												

e. *Forage maize registered for the "SFEI" AEM*

Maïs fourrager SFEI		FE (tCO_2e/kg substance active)	Source	Dose "anciens signataires" SFEI	Dose moyenne référence (kg QSA/ha, cf Le Rohellec 2010)	Source	Emissions (tCO_2e/ha)					Source
							SFEI (1,4 UGB/haSFP)	Référence pour 1,4 UGB/haSFP	Référence pour 1,8 UGB/haSFP			
							1,4	1,4	1,8			
Production engrais	N	0,0053	ADEME (2010)	2	63,7	FE : Pellerin et al. (2013) Dose : Le Rohellec (2010)	0,01	0,34	0,34			
Production engrais	P	0,0006	ADEME (2010)	3	25,4	idem	0,00	0,01	0,01			
Production engrais	K	0,0004	ADEME (2010)	8	21,5	idem	0,00	0,01	0,01			
Production phytos	Herbicides	0,0090	ADEME (2010)	0,16	0,300	EPC 2011, Aubertot et al (2005)	0,00	0,00	0,00			
Production phytos	Fongicides	0,0061	ADEME (2010)	0	0,000		0,00	0,00	0,00			
Production phytos	Insecticides	0,0253	ADEME (2010)	0,01	0,010		0,00	0,00	0,00			
Production phytos	Regulateurs	0,0085	ADEME (2010)	0	0,000		0,00	0,00	0,00			
Production phytos	Molluscides	0,0090	ADEME (2010)	0	0,000		0,00	0,00	0,00			
Champ	engrais N minéral	0,006	tCO_2e/kgN, Pellerin et al. (2013)	2	63,7	FE : Pellerin et al. (2013) Dose : Le Rohellec (2010)	0,01	0,37	0,37			
Champ	épandage N organiques	0,007	tCO_2e/kgN, IPCC 2006 et CITEPA 2013	61	124,4	idem	0,41	0,83	0,83			
Champ	N_2O déjections en bâtiment "toute l'année"						0,17	0,17	0,22			IPCC 2006, CITEPA 2013
Champ	CH_4 déjection en bâtiment "toute l'année"						1,67	1,67	2,15			IPCC 2006, CITEPA 2015
Champ	CH_4 entérique						2,79	2,79	3,59			IPCC 2006, CITEPA 2016
Mécanisation (construction engins + carburant)		0,0257786	tCO_2/ha, Bilan Carbone v6.1	1			0,03	0,03	0,03			
Emissions amont (y compris carburant)							0,04	0,39	0,39			
Emissions N_2O au champ/bâtiment (tCO_2e/ha)							0,59	1,37	1,42			
Emissions N_2O au champ hors cheptel (tCO_2e/ha)							0,42	1,20	1,20			
Emissions CH_4 au champ/bâtiment (tCO_2e/ha)							4,47	4,47	5,74			
Emissions GES totales (tCO_2e/ha)							5,10	6,22	7,55			
Emissions GES totales hors cheptel (tCO_2e/ha)							0,46	1,59	1,59			
Emissions GES totales (tCO_2e/litre de lait)												
Emissions GES totales (tCO_2e/100 kg viande vive)												

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