RESEARCH CHALLENGE FUND PROJECT 03/2010

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Reducing Greenhouse Gas Emissions from the Northern Ireland dairy sector through the development of (1) an on-line management tool, and through (2) an on-farm research programme targeted at improving dairy cow health, reproductive efficiency and longevity, via the adoption of improved management strategies during the 'transition period'

INDUSTRY REPORT ON

THE DEVELOPMENT OF AN ONLINE CALCULATOR FOR ESTIMATING GREENHOUSE GAS EMISSIONS FROM NORTHERN IRELAND DAIRY FARMS, AND AN EXAMINATION OF EMISSIONS FROM A NUMBER OF FARMS

DELIVERABLE FROM TASK 3

Research team

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Executive summary

In Northern Ireland (NI) it is estimated that 26% of greenhouse gas (GHG) emissions come from the agricultural sector. In recognition of the contribution of the dairy sector to these emissions, funding from DARD and AgriSearch through the Research Challenge Fund (RCF) was secured to 1) develop an online tool to assess GHG emissions from the dairy sector, and 2) to establish an on-farm research project targeted at improving dairy cow health, reproductive efficiency and longevity, via the adoption of improved management strategies during the ‘transition period’.

This industry report provides (i) a description of the GHG calculator and the models which underlie it, (ii) a validation of the calculator by comparing its outcomes with those of other calculators, and (iii) total GHG emissions for the dairy farms involved in the on-farm research project.

The model developed used a life cycle assessment (LCA) approach to quantify GHG emissions from various sources within the farm gate of dairy production systems. Emission sources included enteric fermentation, manure management, fertiliser manufacture and application, concentrate production and transportation, land use change, fuel and electricity use and other sources (e.g. manufacture of veterinary products). Some of the underlying assumptions were based on research findings specific to Northern Ireland farming conditions. The model was then used as the basis for the development of an online GHG calculator for dairy production systems.

The AFBI GHG calculator was then validated by comparing the GHG emissions generated by the calculator for nine NI farms, with those obtained from three other GHG calculators. A number of assumptions were required to standardise data input across the calculators. Total GHG emissions and emissions per kilogram of milk were relatively similar across the four calculators, with individual farm variation captured accurately and consistently across all calculators. The contribution of each emission source varied slightly, by up to five percentage units across all calculators. This comparison provides confidence in the ability of the AFBI calculator to estimate GHG emissions for NI dairy farms, and in its ability to be a useful tool in the development of mitigation strategies to reduce GHG emissions at farm level.

The AFBI calculator was then used to estimate GHG emissions from seven of the nine NI dairy farms which participated within the on-farm component of this project. The seven farms surveyed ranged in size from 71 to 239 ha (average 119 ha) of which 88% on average was grassland. The average herd size and milk production were 184 dairy cows (ranging from 117 to 373 cows/farm) and 8,761 kg milk/cow (ranging from 7,610 to 10,602 kg milk/cow) respectively. Across all seven farms GHG emissions ranged from 1.02 to 1.19 kg CO_2e/kg of milk produced (average 1.11 g CO_2e/kg of milk), excluding carbon sequestration. When carbon sequestration was taken into account, total GHG emissions were reduced by 13% on average. The primary contributors to the carbon footprint of these farms were enteric methane emissions from rumen fermentation (40%), manure management (18%) and concentrate production and transportation (16%).

Wider application of this online tool will help provide an accurate inventory of emissions across NI dairy systems, and help identify appropriate mitigation strategies at the individual farm level.

Introduction

Currently there are major uncertainties associated with both the actual level of greenhouse gas (GHG) emissions from the agri-food sector in Northern Ireland (NI), and the impact of changes in farming practices on GHG emissions (Mayne, 2009). Research is urgently required to address these issues if the contribution of agriculture to climate change is to be more clearly understood and appropriate mitigation action taken.

In NI it is estimated that 26% of GHG emissions come from the agricultural sector, with methane (CH_4) from cattle and sheep and nitrous oxide (N_2O) from soils being the major sources (Thistlethwaite *et al*., 2012). Consequently, DARD has identified the need to develop business efficient mitigation strategies to reduce GHG emissions as a key strategic priority. Enteric fermentation by livestock in particular is a significant contributor to GHG emissions, representing 85% of total agricultural CH_4 emissions in Northern Ireland in 2010 (Thistlethwaite *et al*., 2012).

In recognition of the contribution of dairying to NI's GHG emissions, AgriSearch and DARD, through the Research Challenge Fund programme, funded a major project to examine options to reduce emissions from the dairy sector. This project comprised two main components:

1) The development of an on-line management tool to assess GHG emissions from the dairy sector.
2) An on-farm research programme targeted at improving dairy cow health, reproductive efficiency and longevity, via the adoption of improved management strategies during the 'transition period'.

With regards the 'on-line tool', this industry report has been prepared to:

i) Provide a description of the development of the on-line tool ('calculator') and the underlying models associated with this tool.
ii) Validate the GHG 'calculator' by comparing its outcomes with those of other similar tools developed elsewhere in Europe.

iii) Determine GHG emissions across a range of milk production systems in NI, thus providing new information on the effects of different systems of milk production on GHG emissions.

Wider application of this online tool will help provide an accurate inventory of emissions across NI dairy systems, and help identify appropriate mitigation strategies at individual farm level.

Description of the calculator and underlying models

System boundary

The present model used a life cycle assessment (LCA) approach to quantify GHG emissions within the farm gate of dairy production systems. Emission sources include emissions from enteric fermentation (CH_4) and manure management (CH_4 and N_2O), together with a number of other sources associated with milk production systems (Table 1). Primary data requirements and calculation approaches for each emission source are summarised in Figure 1. Emissions arising from enteric fermentation and manure management were calculated based on the age structure and physiological state of the animals within the dairy herd, while emissions from other sources, and carbon sequestration values, were estimated for the dairy production unit (dairy enterprise within a farm) as a whole.

Table 1. GHG emission sources accounted for within the present model

Source of emissions	Individual gas from each source of emissions
Enteric fermentation	CH_4 from enteric fermentation
Manure management	CH_4 from indoor manure storage CH_4 from faeces deposited by grazing cattle N_2O from indoor manure storage N_2O from slurry spreading N_2O from faeces/urine deposited by grazing cattle
Inorganic fertiliser manufacture and application	CO_2e from fertiliser manufacture N_2O from application of N fertilisers CO_2 from application of lime and urea
Concentrate production and transportation	CO_2e from concentrate production and transportation
Land use and land use change	N_2O from plant residues CO_2e from land use change CO_2e sink from carbon sequestration
Fuel and electricity use	CO_2e from fuel use for dairying CO_2e from electricity use for dairying
Others	CO_2e from manufacture of veterinary products and silage wraps CO_2e from refrigerant leakage CO_2 expired by animals offered imported forages

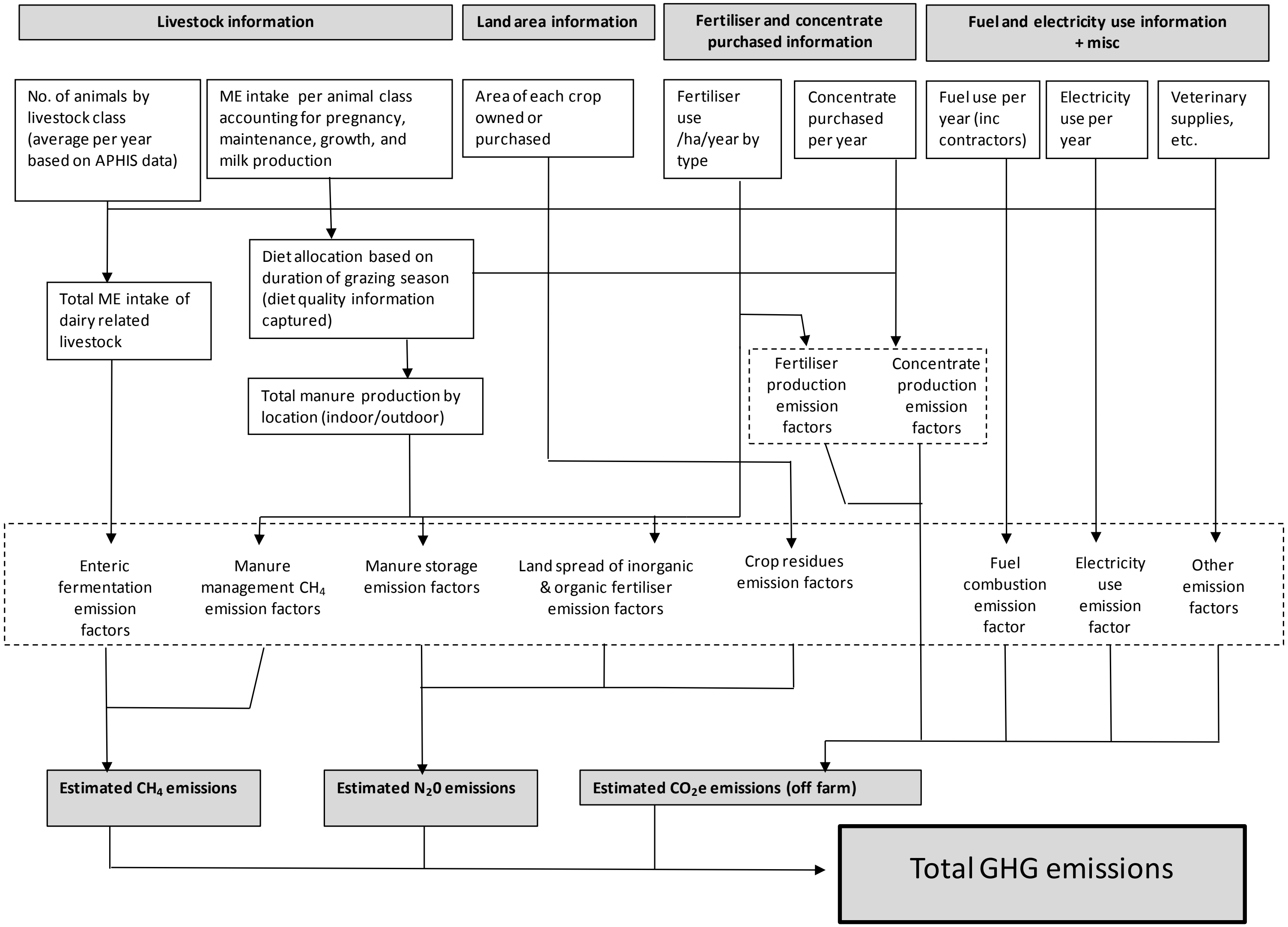

Figure 1. Data requirement and calculation approaches used for each emission source.

Models and assumptions used for each emission source

Emissions from enteric fermentation

Emissions from enteric fermentation account for the majority of total GHG emissions within the farm gate of dairy production systems, with recent studies reporting average contributions from this source of 40% for UK dairy farms (DairyCo, 2012). It is therefore essential to adopt accurate modelling approaches to minimise the errors associated with calculating this important source of emissions. Within the present model, enteric methane emissions from the dairy herd were calculated from total feed intake on an individual animal basis, using the following steps. The 'dairy herd' was divided into five separate groups according to their physiological state, namely, lactating dairy cows (milking and dry period), breeding bulls, and three groups of heifers (over 2 years, 1 to 2 years and less than 1 year). Enteric CH_4 emissions were calculated for each group from total metabolisable energy (ME) requirements, with CH_4 energy (CH_4-E) output determined as a proportion of ME intake. Total ME requirements for lactating cows (maintenance, lactation, liveweight change, pregnancy and grazing activity) were estimated from the FiM rationing system (Agnew *et al*., 2004) and AFRC (1993). The FiM system was developed to incorporate improvements in our understanding of energy partitioning and utilisation associated with higher yielding dairy cows, with this system having been adopted within the UK for rationing dairy cows. ME requirements for maintenance for the other four groups of animals were estimated from metabolic live weight ($kg^{0.75}$) multiplied by a factor of 0.59 (Jiao *et al*., 2013), while ME requirements for liveweight gain, grazing activity and pregnancy (for adult heifers) were estimated from AFRC (1993). The ratio of CH_4-E/ME intake for all groups was calculated from the following equation (Equation 1), which indicates a reduction in this ratio with increasing ME intake. This equation was derived from calorimeter CH_4 data from dairy cows (n = 579) (Yan *et al*., 2010) and beef cattle (n = 108) (Yan *et al*., 2009) obtained from studies undertaken at AFBI Hillsborough during the last 20 years.

$$CH_4\text{-E/ME intake (MJ/MJ)} = 0.146 - 0.00021 * \text{ME intake} \quad (1)$$

Emissions from manure management

The ME requirement data described above were also used to calculate total DM intake of forages (grazed grass, grass silage etc.) after subtraction of ME supplied from offered concentrates. Total DM intake data (forages and concentrates) were then used to calculate organic matter (OM) and N excretions in faeces and urine for each group of animals using the following four equations (Equations 2 to 5). These equations were derived from two datasets, one for dairy cows (n = 564) (Yan *et al*., 2006) and one for growing cattle (n = 286) (Yan *et al*., 2007).

Dairy cows:

$$\text{Manure OM output} = \text{DM intake} * (1 - \text{ash content}) * (0.12 * \text{FP} + 0.127) \quad (2)$$

$$\text{Manure N output} = 0.722 * (\text{DM intake} * \text{N content}) \quad (3)$$

Dairy bulls and heifers:

$$\text{Manure OM output} = \text{DM intake} * (1 - \text{ash content}) * (0.12 * \text{FP} + 0.127) \quad (4)$$

$$\text{Manure N output} = 0.775 * (\text{DM intake} * \text{N content}) \quad (5)$$

where FP is the forage proportion in the diet (kg/kg DM); DM intake, OM intake and manure OM output are expressed as kg/d, N intake and manure N output as g/d, ash content as kg/kg DM, and N content as g/kg DM.

Manure OM outputs were then used to calculate CH_4 emissions arising from indoor manure storage, slurry spreading and faeces voided during grazing, using the approaches of IPCC (2006a). These calculations take account of manure management systems (storage system and spreading techniques), length of grazing period and climate conditions at the individual farm level. The calculation also takes account of manure imports and exports.

Manure excreted during confinement periods was assumed to be 'stored'. Data on nitrogen contained within 'stored' manure were used to calculate direct N_2O emissions, as well as indirect emissions from volatile N losses, using IPCC (2006a) emissions factors. These calculations take account of manure management systems and climate conditions at the individual farm level. Data describing N spread in slurry, and information on N voided by grazing animals in faeces and urine, were used to calculate direct N_2O emissions from nitrification and denitrification processes in the soil and indirect emissions associated with N volatilisation, N leaching and N lost in runoff. The emission factors (EFs) of IPCC (2006a) were used to calculate emissions from these sources according to length of grazing period and climate conditions at the individual farm level. Emissions arising from imported and exported manure were accounted for using the same methodology.

Emissions from inorganic fertiliser manufacture and application

Carbon dioxide emissions from the manufacture of chemical fertilisers used within the dairy enterprise included production of urea N (1.9913 kg CO_2e/kg N) and other N fertilisers (5.7896 kg CO_2e/kg N), P_2O_5 fertilisers (0.6462 kg CO_2e /kg P_2O_5) and K_2O fertilisers (1.5167 kg CO_2e/kg K_2O) (Wood and Cowie, 2004). Nitrous oxide emissions following the application of inorganic N fertilisers, and CO_2 emissions from soil caused by the application of lime and urea, were calculated using methodologies of IPCC (2006a and 2006b).

Emissions from concentrate production and transportation

As the present model has been developed primarily for grassland-based systems, the assumption was made that most ingredients for concentrate feeds were imported. Two concentrate 'types' were included in the model, one for dairy cows and one for the other four groups of livestock defined within the model (breeding bulls, and heifers over 2 years, 1 - 2 years and less than one year). A 'standard' ingredient list and 'standard' proportional inclusion level were identified for each of these two concentrate types through an informal survey of a number of feed manufacturers/nutritional consultants in Northern Ireland. Emission factors associated with the production and transportation of these ingredients were based on the system described by the Scottish Agriculture College (The Scottish Government, 2011). The calculated emission value associated with the production and transportation of each 1 kg DM of concentrates offered was 0.7418 kg CO_2e for dairy cows, and 0.6170 kg CO_2e for breeding bulls and heifers.

Carbon sequestration and emissions from land use and land use change

The carbon sequestration value adopted for permanent grassland associated with the dairy enterprise within the present model was 2.6 t CO_2e per hectare per year. This value was obtained from a long term study (40 years) in which the accumulation of carbon within the top 15 cm of soil underlying a perennial ryegrass sward was measured, with the data having been adjusted to reflect a total available N application rate of 100 kg N per hectare per year (Scot Laidlaw, personal communication). Nitrous oxide emissions from plant residues were calculated using methodologies of IPCC (2006a and 2006b).

Emissions from land use change relating to the dairy enterprise were only included when changes occurred during the past 20 years. A total of 12 land use change scenarios were included within the model, and these accounted for the most likely land use change scenarios arising within grassland-based dairy systems in Europe. Change scenarios represented those which could occur between four types of land use, namely: permanent grass, temporary grass, crops and forestry. The EFs adopted for each type of land use change were those published by Smith *et al*. (2010).

Emissions from fuel and electricity use

Emission factors for use of electricity and fuel, namely red diesel, white diesel, heating oil and petrol, were 0.5246 kg CO_2e/kWh, 2.6676, 2.6676, 2.6492 and 2.3117 kg CO_2e/l, respectively (Carbon Trust, 2012). When information on electricity and fuel consumption were unavailable, default values were used to determine electricity and fuel consumption per litre of milk produced (The Scottish Government, 2011) in order to account for the emissions from these two sources. The present model also included emissions from fuel which was used by contractors and not supplied by the host farmers.

Emissions from other sources

Emissions relating to the manufacture of plastic film for silage wrap and veterinary products, and emissions from refrigerant leakage were based on the system described by the Scottish Agriculture College (The Scottish Government, 2011).

When animals consume home grown forages, it is normally assumed that the amount of CO_2 expired offsets carbon sequestrated by these forages during their growth. However, carbon sequestration during the growth of imported forages is accounted for on the farm where the forage is produced, and as such CO_2 emissions expired by animals offered imported forages were included in the present calculation as an additional emission source, using Equations (6) and (7). These equations were developed from calorimeter data of young animals and dry and lactating dairy cows (n = 987) measured at this Institute since 1992 (Aubry and Yan, 2013).

Dairy cows: CO_2 output (l/d) = 12.71 * CH_4 output (l/d) – 457 (6)

Dairy bull and heifers: CO_2 output (l/d) = 12.71 * CH_4 output (l/d) – 216 (7)

Allocation of emissions between milk and meat production

Total CO_2e emissions within the farm gate for the dairy enterprise were separated into emissions associated with the production of milk and emissions associated with the production of meat. The allocation factor for milk was determined using Equation (8), as proposed by the International Dairy Federation (IDF, 2010).

Allocation factor for milk = 1 – 5.7717 * M_{meat}/M_{milk} (8)

Where M_{meat} = sum of live weight (kg) of all cattle sold including bull calves and culled mature animals, and M_{milk} = sum of milk (kg) sold and corrected to the standard milk (4.0% fat and 3.3% CP).

Data input to the on-line tool and overview of outputs

All of the key tables used to input required farm data and to present output results (as included within the on-line tool) are included in Appendices 1 to 3. The input tables are organised into six different pages covering data on land/crops, livestock, grazing/forage, fertiliser/manure, fuel/electric and land use (Appendix 1), and offer the user with a choice of drop down menus and default values depending on the parameters.

Once all the required data have been entered into the relevant tables, total GHG emissions are calculated for each farm by the calculator. The programming language VB.NET was used to combine the equations described above and calculate the overall carbon footprint. Emissions are expressed in terms of carbon dioxide equivalents (CO_2e) both with and without carbon sequestration. Total CO_2e emissions estimated from the AFBI calculator for the dairy enterprise within the farm gate are separated into emissions associated with the production of milk and emissions associated with the production of meat. Unless otherwise stated, all results reported below, associated with each emission source, were based on emissions derived from milk production only.

For each farm, a summary report is generated by the calculator, and an example is presented in Appendix 2. Total emissions are provided per kilogram of milk produced (corrected for fat and protein content), and a series of histograms present these emissions according to all major sources. The farmer report includes a summary of the livestock and land use data that were entered into the calculator. A number of efficiency indicators are also calculated and presented, including milk from forage and efficiency of grass utilisation. Lastly, the carbon footprint from the dairy enterprise is summarised, with emissions presented with and without sequestration on a per kilogram of milk, per hectare and per cow basis.

In addition, a second report can be generated for research purposes (see example in Appendix 3). This second report provides total GHG emissions allocated to milk and meat productions from the dairy enterprise, as well as a further breakdown according to 17 different sources of emissions.

A user guide was produced to assist when entering data into the calculator and when interpreting the outputs presented in the farmer and research reports (Appendix 4).

Validation of the calculator

Introduction

Greenhouse gas calculators have been developed to quantify emissions arising from the production or manufacture of goods or products. However, the emissions boundary and methodology adopted within different calculators vary, making direct comparisons between values generated difficult. To standardise calculation principles, enabling a more valid comparison, the International Dairy Federation have produced guidelines for the production and reporting of GHG emissions from dairying (IDF, 2010). Provided minor differences in methodology are clearly defined, comparisons between calculators should be possible. The objectives of this section of the report were to compare GHG emissions per kilogram of fat corrected milk generated from the AFBI calculator with those calculated using three other GHG calculators, and to identify the source of any differences.

Materials and methods

Data were collected from nine NI dairy farms (farms involved in the EU Dairyman project) which included a range of production systems. Each farm's data were then inputted into the following GHG calculators

- AFBI Dairy GHG calculator
- Dairyman GHG calculator – Tier 1
- Dairyman GHG calculator – Tier 2
- French GHG calculator (S. Morrison, personal communication)

The data collected from these farms included the following information:

Animal counts by type i.e. dairy cows, dairy heifers
Land area and crop type
Land use change
Crop and feed imports
Manure type/storage system
Dairy cow pregnancy rate

Fertiliser/lime use

A number of assumptions had to be made to standardise data input across the calculators as the input parameters varied slightly between each calculator. The main assumptions are listed below:

- Within the French and Dairyman calculators specific EFs were applied to imported feed ingredients (e.g. barley, wheat). Within the AFBI calculator feed ingredients were grouped under concentrate types, with the EF used based on 'standard' Northern Ireland dairy and heifer concentrates. There was considerable variation in the EF of feed ingredients used within each of the calculators. Thus, to enable a more valid comparison, the EF of each feed ingredient within the Dairyman calculators was adjusted to that used within the AFBI calculator, while the ratio of feed ingredients within the French calculator was adjusted to ensure a similar EF per kg of concentrates to that used in the AFBI calculator.

- Within the French calculator, age at first calving and replacement rate were assumed so as to best match the number of heifers present on the farm. This information was not required within the remaining calculators, although within these models the total number of young stock was split across age bands.

- Gross energy of the diet was assumed to be 18.45 MJ/kg DMI within the French calculator, with digestibility of grass silage and grazed grass assumed to be 680 g/kg DM. The AFBI calculator is based on the metabolisable energy (ME) content of the diet with grass silage and grazed grass assumed to have a ME of 10.9 and 11.3 MJ/kg DM. The overall digestibility of concentrates was standardised across the French and AFBI calculators with total diet digestibility typically in the range of 700 - 740 g/kg DM and 680 - 720 g/kg DM for the dairy cow and heifer diets, respectively. Within the Dairyman calculators the overall digestibility of the diet offered to cows and heifers was 750 and 650 g/kg DM respectively. Information on total concentrates fed was supplied for each farm and, where required, the allocation of concentrates to the heifer component of the dairy enterprise was based on the average proportion obtained from Northern Ireland CAFRE Benchmarking (10% of total farm concentrates).

- All grassland was assumed to be permanent grassland with no land use change. All calculators reported carbon sequestration values for permanent grassland but as recommended (IDF, 2010) sequestration was excluded from the calculator comparison.

- Global warming potential (GWP) was standardised, with the GWP of CH_4 and N_2O assumed as 25 and 298, respectively.

- Within the French model the area of grassland was calculated rather than inputted. To ensure results were comparable the calculated value was overwritten with the actual grassland area on each farm. Grass yield was standardised across all farms and calculators.

- The functional unit varied between calculators with the French and Dairyman calculators expressing emissions on a per kilogram of milk basis whereas the AFBI calculator was based on energy corrected milk production. For comparison purposes all values were compared on a fat corrected milk (FCM) basis.

- Within the AFBI calculator the fertiliser type was assumed to be either calcium ammonium nitrate (CAN) or urea with each fertiliser type having a different EF. Fertiliser type was not required within the French calculator nor was the application rate of phosphorous and potassium fertilisers, while both the Dairyman and AFBI calculators could account for the EFs for the production of phosphorous and potassium fertilisers. However, with low or zero application rates of phosphorous and potassium fertilisers on the majority of the nine study farms, the impact on the overall farm emissions would have been low.

- Uniquely, the AFBI calculator included emissions associated with the manufacture of veterinary drugs, plastic film and detergents and emissions from refrigerant leakages. These sources of emissions were grouped with fuel/electricity during the comparison.

Analysis of variance was conducted on the dataset with farm treated as the blocking term and GHG calculator as the treatment.

Results

The variation which existed between farms in total GHG emissions, expressed in terms of carbon dioxide equivalents (CO_2e), was well captured by all calculators (Figure 2), with all calculators reporting the highest and lowest emissions for Farm 8 and Farm 4, respectively. Standard deviation of total emissions across the calculators averaged 4.4% of mean total emissions. On average, 'on-farm' emissions accounted for 71% of total emissions across all calculators with the remaining 29% originating from 'off-farm' sources.

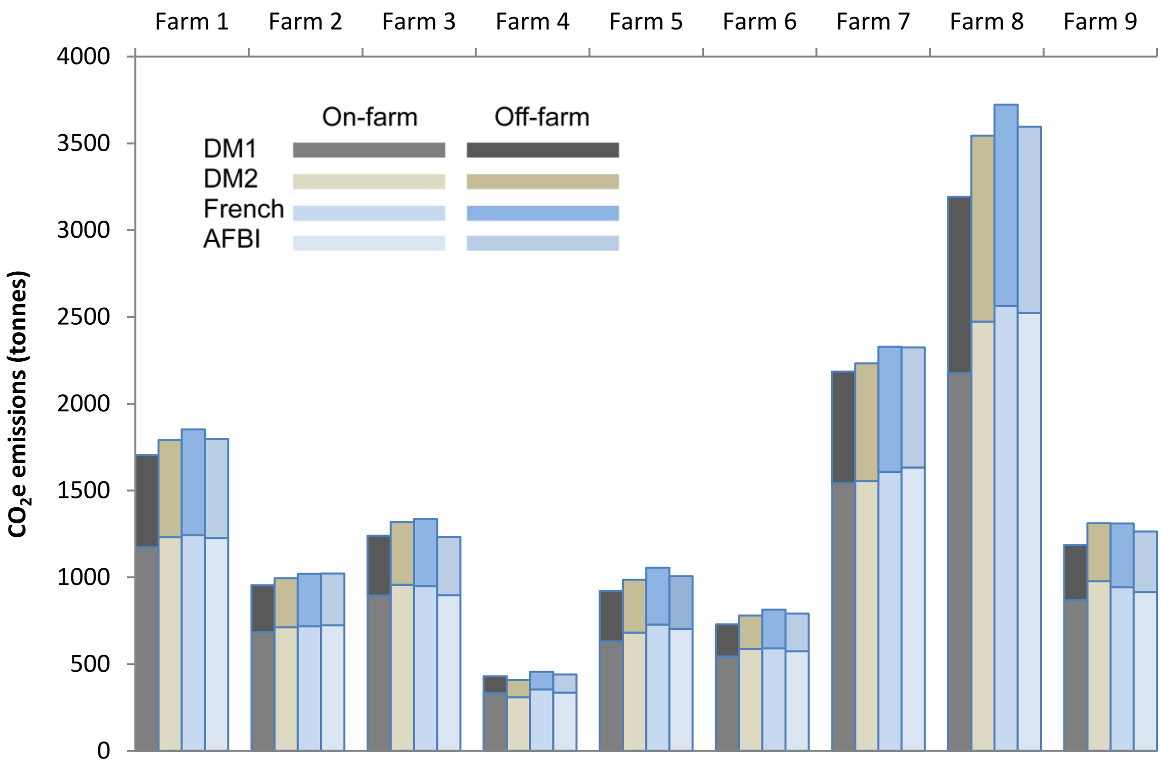

Figure 2. Total GHG emissions per farm (excluding carbon sequestration by permanent grassland). The upper and lower sections of each bar represent 'off-' and 'on-' farm emissions respectively. Total emissions were calculated using the Tier 1 Dairyman calculator (DM1), the Tier 2 Dairyman calculator (DM2), the French calculator and the AFBI calculator.

Total emissions estimated using the Tier 1 Dairyman calculator were significantly lower than those estimated using the remaining calculators (Table 2; $P<0.001$), resulting in lower emissions per kilogram of FCM with this calculator (Table 2; $P<0.001$). Although total emissions were similar across the remaining calculators, the proportions derived from enteric fermetation and fuel/electricity use were significantly greater for the AFBI calculator (Table 2; $P<0.001$). Similarly, both the total and proportion of emissions from land use, manure and fertiliser application were significantly greater for the French calculator. No significant difference in CO_2e/kg FCM was found between the French and AFBI calculators, with values reported by the Dairyman 2 calculator not significantly different to those generated by the AFBI calculator (Table 2).

On an individual farm basis, the ranking of farms by total emissions was relatively consistent across the four calculators with only one rank position movement for Farms 2, 3 and 5 across the calculators. When expressed as kg CO_2e/kg FCM re-ranking of farms across the calculators was again minimal with most notable variation found with Farm 3 (Table 3).

Table 2. Relative contribution of emission sources to the annual CO_2e emissions at farm level as assessed by four greenhouse gas calculators (excluding carbon sequestration by permanent grassland)

	Greenhouse gas calculator				LSD (5%)	Sig.
	AFBI	Dairyman 1	Dairyman 2	French		
Total emissions (tonnes CO_2e/farm)	1497^{b}	1393^{a}	1485^{b}	1543^{b}	66.0	***
Source of emissions (tonnes CO_2e/farm)						
Enteric fermentation	648^{b}	600^{a}	615^{a}	595^{a}	28.2	**
Land use, manure and fertiliser application	411^{ab}	383^{a}	438^{b}	481^{c}	35.9	***
Concentrate and fertiliser manufacture	342^{ab}	331^{a}	351^{b}	392^{c}	18.3	***
Fuel and electricity	96^{c}	80^{b}	80^{b}	74^{a}	1.9	***
Source of emissions (% of total)						
Enteric fermentation	43.5^{c}	43.3^{c}	41.7^{b}	38.9^{a}	0.79	***
Land use, manure and fertiliser application	28.0^{a}	28.3^{a}	30.1^{b}	31.9^{c}	0.86	***
Concentrate and fertiliser manufacture	21.5^{a}	22.4^{b}	22.5^{b}	24.3^{c}	0.78	***
Fuel and electricity	7.1^{c}	5.9^{b}	5.6^{b}	4.9^{a}	0.60	***
Contribution of enteric fermentation to on-farm emissions (%)	60.9^{c}	60.5^{c}	58.1^{b}	55.0^{a}	1.01	***
Emissions per kg of milk produced (kg CO_2e/kg FCM)	1.28^{bc}	1.20^{a}	1.26^{b}	1.31^{c}	0.030	***

LSD - Least significant difference
Sig. – Significance * P< 0.05; ** P< 0.01; *** P< 0.001; NS =non-significant
FCM – Fat corrected milk yield - Milk yield (kg)*(0.4+0.015*Fat Content (g/l)/1.033)

Table 3. Annual greenhouse gas emissions per farm and per kilogram of fat corrected milk output (excluding carbon sequestration by permanent grassland)[1].

Farm	Greenhouse gas calculator			
	AFBI	Dairyman 1	Dairyman 2	French
Total emissions per farm (t CO_2e)				
1	1807 (3)	1704(3)	1790(3)	1852(3)
2	1028(6)	954(6)	995(6)	1020(7)
3	1240(5)	1239(4)	1318(4)	1336(4)
4	443(9)	429(9)	408(9)	455(9)
5	1012(7)	922(7)	986(7)	1055(6)
6	796(8)	728(8)	779(8)	814(8)
7	2339(2)	2185(2)	2232(2)	2329(2)
8	3595(1)	3191(1)	3544(1)	3724(1)
9	1296(4)	1186(5)	1311(5)	1310(5)
Total emissions per farm per kilogram of fat corrected milk (kg CO_2e/kg FCM)				
1	1.21(8)	1.15(6)	1.20(8)	1.24(8)
2	1.47(1)	1.36(1)	1.42(1)	1.46(1)
3	1.24(5)	1.24(4)	1.32(2)	1.34(4)
4	1.33(3)	1.29(3)	1.23(5)	1.37(3)
5	1.24(6)	1.13(7)	1.21(6)	1.30(5)
6	1.23(7)	1.13(8)	1.21(7)	1.26(7)
7	1.38(2)	1.29(2)	1.32(3)	1.38(2)
8	1.16(9)	1.03(9)	1.14(9)	1.20(9)
9	1.26(4)	1.15(5)	1.28(4)	1.27(6)

[1] Ranked position of farm within each model shown in parenthesis

Discussion

There was considerable variation in the methodology by which each model calculated emissions, and in the specific inputs required within each. For example, different approaches were taken for livestock counts, diet quality and land requirements. This meant that many assumptions were required to enable comparisons. Based on these assumptions the outputs from the Dairyman 2, French and AFBI calculators were relatively similar with no difference found in total emissions. When emissions were expressed per unit of output, no significant difference was found between the Dairyman 2 and AFBI calculators, with values obtained from the French calculator similar to those reported by the AFBI calculator. However, estimated emissions per unit of FCM tended to be greater for the French calculator compared to the Dairyman 2 calculator. This difference reflects a combination of lower estimated emissions from land use/manure/fertiliser application and concentrate/fertiliser manufacture from the Dairyman 2 calculator compared with the French calculator.

Despite standardising the emissions associated with the production of imported feeds such as barley and wheat across the Dairyman 2, AFBI and French calculators, emissions attributed to concentrate and fertiliser manufacture differed significantly, suggesting that these differences were derived from the fertiliser manufacture component. The EF to produce 1 kg of nitrogen was almost 5% greater in the French calculator compared to Dairyman 1 and 2, and 7% greater than the EF used with the AFBI calculator. In addition, both the Dairyman and AFBI calculators took account of different EFs associated with the use and manufacture of urea compared to other types of mineral fertiliser. Within the Dairyman 1 calculator, the EF for concentrate feed ingredients was preset, which can explain the lower emissions from this source compared to those obtained from the Dairyman 2 calculator.

Both the French and Dairyman 2 calculators used the same equations for electricity and fuel use (fuel required to transport milk off-farm was excluded) but used different EFs for the production of fertiliser, with a lower EF used by the Dairyman 2 calculator. In terms of emissions from land use, manure and fertiliser application, the French, AFBI and Dairyman 2 calculators differed in the equations used to calculate DM and N intake. The AFBI calculator used exact animal numbers, land areas, crop yields, diet quality parameters for forages and concentrates, and livestock energy and nitrogen balance equations. The French and Dairyman 2 calculators used similar equations to calculate N excretion and DM intake, however the activity and diet digestibility data were captured differently across the calculators. The lower enteric CH_4 emissions produced by the French and Dairyman 1 calculators compared to the AFBI and Dairyman 2 calculators are likely to reflect both differences in how activity data were captured and in the equations used to calculate emissions per animal. The French calculator assumed that 6.15 and 6.28% of gross energy intake was lost as CH_4 for dairy cows and young stock respectively, whereas the Dairyman 2 calculator was based on 6.5% for both livestock types. The AFBI calculator was based on IPCC Tier 3 methodology with energy balance equations based on the research of Agnew *et al*. (2004). The Dairyman 1 calculator was based on IPCC Tier 1 EFs, therefore dairy cows and heifers were assumed to produce 117 and 57 kg CH_4 per year irrespective of the level of animal performance, diet types etc. In view of the contrasting methods used, it was surprising that the CH_4 emissions were relatively similar across the calculators, with a range of less than 10%.

The contribution of each emission source, despite variations by up to five percentage units across the calculators, was similar to results published by DairyCo (2012). Within the first year of a three-year project, the E-CO_2 project used a PAS 2050 and Carbon Trust accredited calculator (complete with IDF compliant calculator) and GHG emission reports for over 400 dairy farms in Great Britain. From this dataset on average 40% of dairy farm emissions were from enteric fermentation and 6% from fuel/electricity use (DairyCo, 2012). These values match closely to the mean of the calculators tested in the current study, with enteric fermentation and fuel/electricity use accounting for 42% and 6% of emissions respectively.

As recommended by the IDF (IDF, 2010), carbon sequestration was excluded from the calculator comparison due to lack of scientific data and technical difficulties in accurately accounting for this carbon sink. However each calculator had the ability to account for carbon sequestration in permanent grassland. The French calculator assumed a sequestration rate of 1.8 t and 0.7 t CO_2e/ha/year for swards less than 30 years of age and over 30 years of age, respectively. In addition, carbon sequestration from hedgerows was accounted for at 1.8 t CO_2e per hectare of hedgerow per year. The rate of carbon sequestration within the Dairyman calculators was at the user discretion but was defaulted to 1.8 t CO_2e/ha/year with no contribution from forestry or hedgerows. A distinction between mineral and organic soils was made with a loss of 7.3 t CO_2e/ha/year assumed for organic soils (adjustable by user). Within the AFBI calculator, the carbon sequestration rate was set at 2.6 t CO_2e/ha/year with no contribution from hedgerows or forestry. These differences in carbon sequestration rates could amount to a 178 t range in CO_2e sequestrated from 100 hectares of permanent grassland (for mineral soils).

Conclusion

Despite many assumptions having to be made and differences in methodology both in how activity data were captured and in how emissions were calculated per animal or per hectare, total GHG emissions and emissions per kilogram of FCM were relatively similar across the calculators with individual farm variation captured accurately. This comparison provides confidence in the ability of any of the four calculators to estimate GHG emissions for dairy farms and provides guidance on how to compare and interpret the results of different calculators despite differences in methodology. Through understanding the relative contributions of the sources of GHG within a dairy farm, mitigation strategies at farm, region and country levels can be developed.

Calculation of the GHG footprint of dairy farms involved in the 'on-farm' dry cow management project

Collection of farm data

Nine NI dairy farms were recruited to participate in an 'on-farm' dry cow research programme. The farms were chosen to represent a range of milk production systems, although to meet the requirements of the study all farms had annual milk yields in excess of 7,000 l/cow. The nine participating farms were geographically spread across NI (Figure 3).

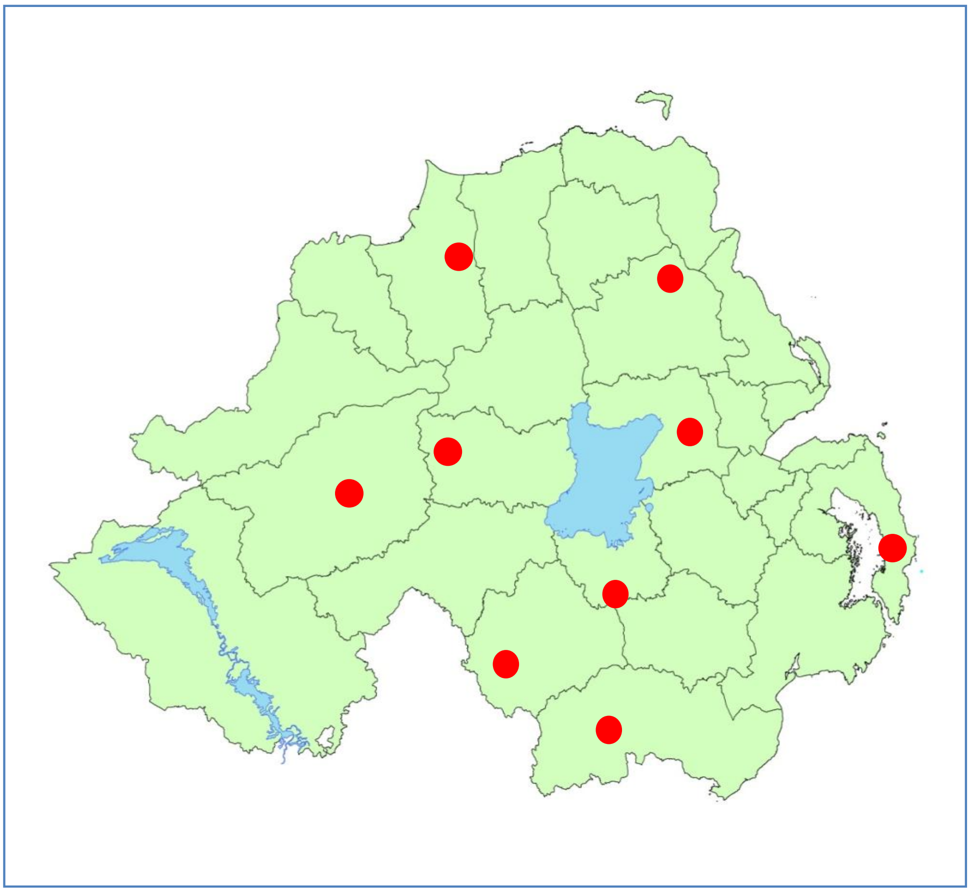

Figure 3. Map highlighting the locations of the nine farms involved in the 'on-farm' dry cow management project.

It was not possible to obtain the necessary data from two of the nine farms participating within the study. Data from the remaining seven farms were collected by an AFBI staff member during routine visits to these farms, and checked for accuracy.

Results and discussion

Farm type and performance data

Across the seven farms surveyed, average herd size was 184 cows (ranging from 117 to 373 cows/farm), while annual milk production was 8,497 l/cow (ranging from 7,388 to 10,294 l/cow) (Table 4). This is markedly above the national average figures for NI of 86 cows and 6,676 l/cow (DARD, 2012), indicating that the participating farms had both above average herd sizes and milk production levels. Nevertheless, the range obtained in total milk production (926,634 to 3,914,401 kg/farm/year) indicates that these seven farms represented a diversity of scale of dairy farming systems (Table 4).

Table 4. Farm characteristics and performance data (average, minimum and maximum) across the seven farms surveyed

		Average	Minimum	-	Maximum
No. of dairy cows		184	117	-	373
No. of heifers		142	72	-	353
Milk sold	*l/cow/yr*	8,497	7,388	-	10,294
Milk fat	*%*	3.96	3.85	-	4.06
Milk protein	*%*	3.20	3.12	-	3.30
Total milk sold	*kg/yr**	1,660,753	926,634	-	3,914,401
Land area	*ha*	119	71	-	239
Stocking rate	*ce/ha/yr*†	2.6	1.9	-	3.5
Concentrate use	*kg/cow/yr*	2,564	2,002	-	2,976
Concentrate use	*kg/kg milk*	0.29	0.25	-	0.31
Fertiliser use	*kg N/ha/yr*	185	152	-	228
No. of months grazing		6	4	-	7
Replacement rate	*%*	27	20	-	48

* Energy corrected milk production
† ce: cow equivalents (annual average number of cows, bulls, heifers 2+, heifers 1 to 2 yr and heifers <1 yr, multiplied by the appropriate cow equivalent coefficient of 1.0, 1.0, 0.8, 0.6 and 0.4, respectively) per hectare of grassland

The seven farms ranged in size from 71 to 239 ha (average 119 ha) of which 88% on average was grassland. Each farm on average used 2,564 kg concentrate/cow/year, corresponding to 0.29 kg concentrate/kg milk produced (Table 4). On average across all seven farms, fertiliser N was applied at an overall rate of 185 kg N/ha.

GHG emissions by source

Across the seven farms, total GHG emissions from the dairy enterprise ranged from 1,231 to 4,704 t CO_2e/farm/yr, excluding carbon sequestration. On average across the seven farms, 86% of these emissions were associated with milk production, with the remaining 14% of total emissions allocated to meat production within the dairy enterprise. The variation between farms in total GHG emissions allocated to milk production is represented in Figure 4, excluding carbon sequestration.

When expressed per kilogram of milk produced, total GHG emissions ranged from 1.02 to 1.19 kg CO_2e/kg of milk produced (average 1.11 kg CO_2e/kg of milk), excluding carbon sequestration (Figure 4). On average, 'on-farm' emissions accounted for 75% of total emissions.

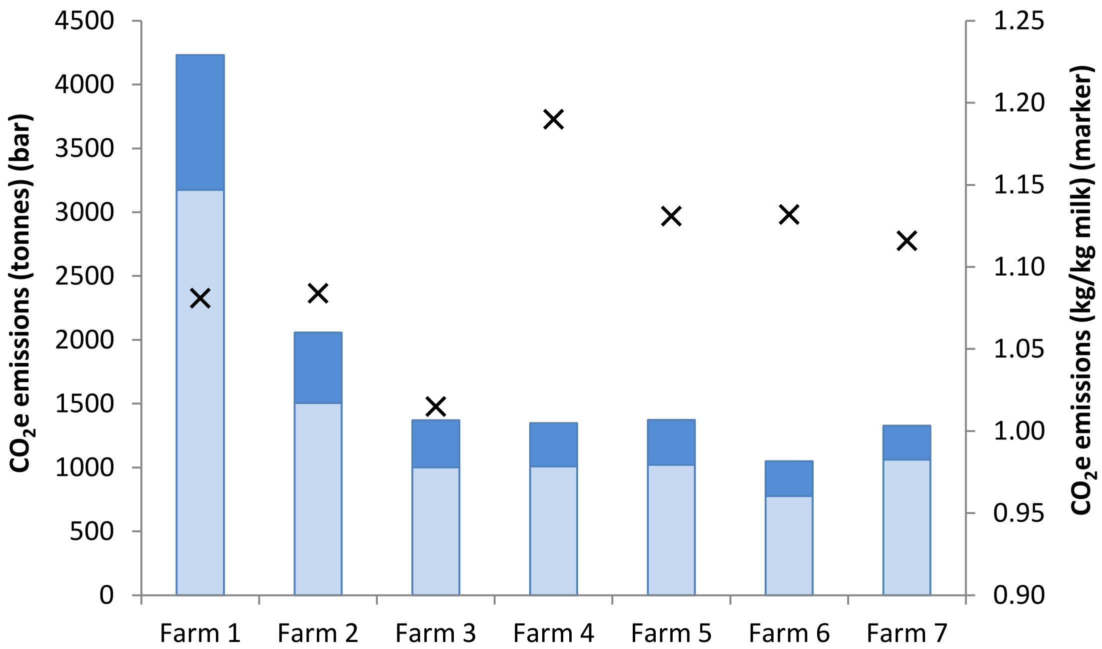

Figure 4. Greenhouse gas emissions allocated to milk production across each of the seven farms, expressed either as total emissions per farm (the upper and lower sections of each bar represent 'off-' and 'on-' farm emissions respectively) or as emissions per kilogram of milk produced (× marker). All emissions exclude carbon sequestration by permanent grassland.

When taking carbon sequestration into account, total GHG emissions were reduced by 13% on average (ranging from 10 to 17%), with total GHG emissions ranging from 0.89 to 1.07 kg CO_2e/kg of milk across all farms (average 0.97 kg CO_2e/kg of milk) (Table 5).

Table 5. Annual (average, minimum and maximum) GHG emissions (CO_2e) allocated to milk production across the seven farms surveyed (excluding and including carbon sequestration).

		Average	Minimum	-	Maximum
Excluding sequestration					
Total emissions for milk production	*tonnes*	1,822	1,049	-	4,230
Allocation factor for milk production	*% of tot.**	*86*	*77*	-	*90*
Emissions per cow	*t/cow*	9.6	8.9	-	11.3
Emissions per ha	*t/ha*	15.0	12.0	-	19.0
Emissions per kg of milk produced	*kg/kg milk*[†]	1.11	1.02	-	1.19
Source of emissions:					
Enteric fermentation	*%*	40	37	-	43
Manure	*%*	18	15	-	21
Fertiliser	*%*	13	11	-	15
Concentrate	*%*	16	12	-	18
Land use	*%*	5	2	-	12
Fuel, electricity	*%*	5	3	-	7
Other sources	%	3	2.7	-	3.3
Including sequestration					
Total emissions for milk production	*tonnes*	1,600	880	-	3,810
Emissions per cow	*t/cow*	8.4	7.5	-	10.2
Emissions per ha	*t/ha*	13.1	10.0	-	17.0
Emissions per kg of milk produced	*kg/kg milk*[†]	0.97	0.89	-	1.07

[*] Percentage of total CO_2e emissions from the dairy enterprise allocated to milk production, with the remaining percentage of total emissions allocated to meat production from the dairy enterprise.
[†] Energy corrected milk.

A recent large scale study in the UK (but not covering NI) estimated the carbon footprint per litre of milk produced across 415 farms, excluding carbon sequestration, and reported an average carbon footprint of 1.31 kg CO_2e/l of fat corrected milk (FCM) (DairyCo, 2012). When expressed on a FCM basis instead of an energy corrected milk basis, the average carbon footprint across the seven farms within the current study was 1.14 kg CO_2e per litre of FCM. This value is still substantially lower than the value obtained within the DairyCo study. While the scale of the current study (seven farms) was clearly much lower than that within the DairyCo study (415 farms), it has already been noted that these seven farms tended to be large enterprises, with an average milk production of 8,500 l/cow, compared to 7,490 l/cow within the DairyCo study. This is likely to explain why the range of GHG emissions obtained in the present study was relatively narrow (1.05 to 1.23 kg CO_2e/l of FCM) compared to the range of values reported by DairyCo (2012) (0.83 to 2.8 kg CO_2e/l of FCM). Variability in total GHG emissions per farm is likely to increase as the AFBI GHG calculator is applied to a more diverse range of farming systems across NI. It is also true that the calculations used within the two studies differed quite substantially, and this will also have contributed to the differences observed in the overall carbon footprint.

The breakdown of total GHG emissions allocated to milk production (CO_2e/kg milk) from each emission source is presented in Table 5 (excluding sequestration), with these data having been presented graphically in Figure 5.

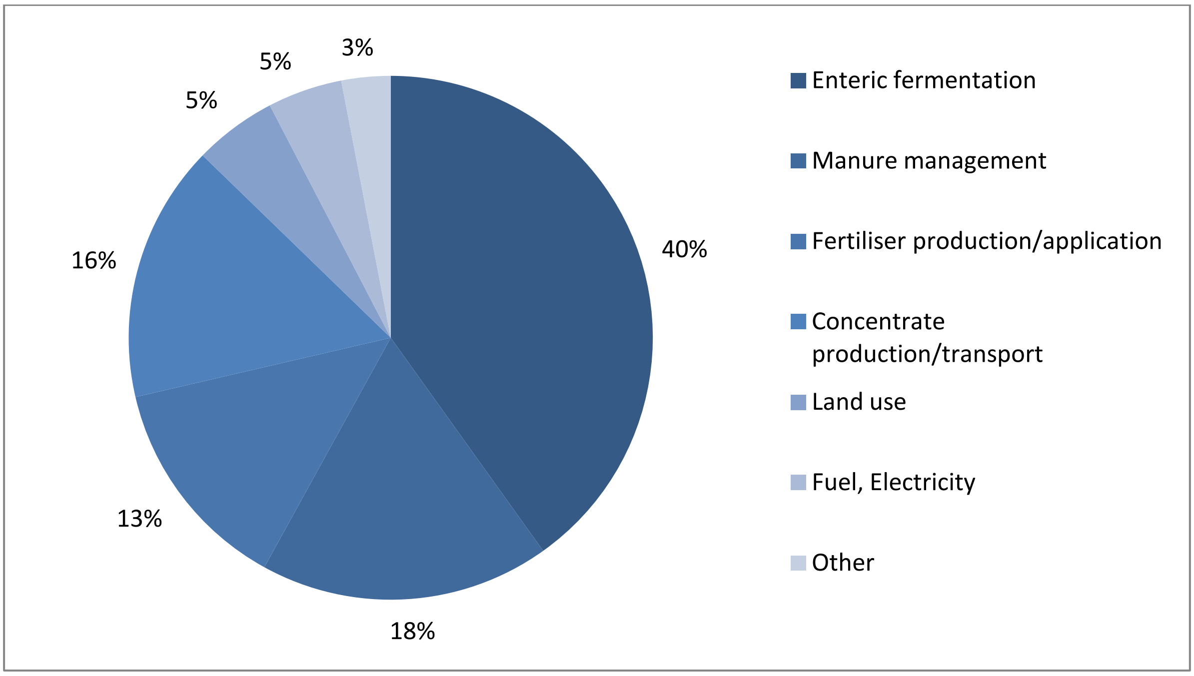

Figure 5. Average breakdown by source of GHG emissions allocated to milk production (CO_2e/kg milk), across the seven farms surveyed.

Enteric CH_4 emissions accounted for the majority of emissions on all farms (40% on average), suggesting that strategies aimed at reducing CH_4 production per litre of milk produced by dairy cows have real potential to reduce the overall carbon footprint of dairying.

Emissions from manure management and concentrate production/transport represented the next two most important sources of GHG emissions, followed by fertiliser production/application (Figure 5). Manure and fertiliser applications represent major sources of N_2O emissions – a GHG 298 times more potent than CO_2. Improving fertiliser use efficiency and manure management strategies, and improving concentrate use efficiency, have the potential to further reduce the overall carbon footprint of the farm. Fuel/electricity on average represented only 5% of the total GHG emissions across the seven farms.

Factors affecting GHG emissions

The present study demonstrated the successful application of the AFBI GHG calculator, developed as part of this project, to accurately determine GHG emissions across a diverse range of production systems. While the number of farms involved in the study was limited, this small dataset provided some evidence of relationships between some of the main farm variables and GHG emissions.

Previous life cycle assessment work on dairy enterprises indicated that strategies effective at reducing GHG emissions at the individual farm level included increased milk yield per cow, reduced concentrate feed rate, reduced replacement rate, reduced stocking rate, increased milk solids concentrations and reduced N fertiliser applications (O'Brien and Shalloo, 2011; Kristensen *et al*., 2011; DairyCo, 2012). In the present study, GHG emissions tended to decrease with increasing milk production per cow and increasing milk protein content (Figures 6a and 6b). In addition, total emissions tended to decrease with decreasing fertiliser application rates (Figure 6c).

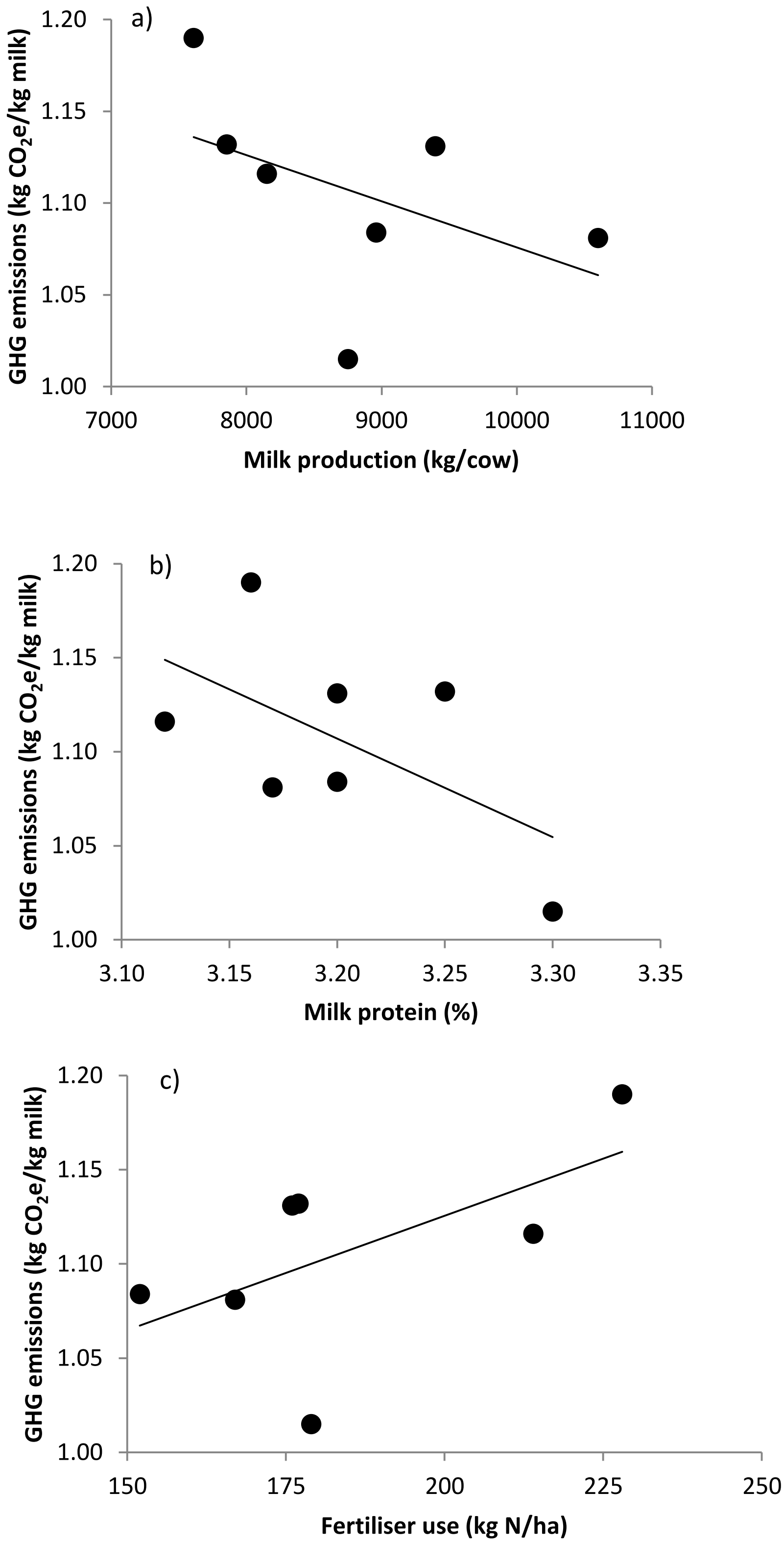

Figure 6. GHG emissions per farm (kg CO_2e/kg of energy corrected milk) versus a) milk production (kg/cow), b) milk protein content (%) and c) fertiliser use (kg N/ha). A linear trend has been highlighted within each dataset.

In practice however, interrelationships exist between parameters describing different production systems, and no single factor is likely to explain most of the variation between farms. Further analyses involving a much greater number of NI farms are required to investigate these relationships further, with the GHG calculator developed within this project providing a robust tool to allow these analyses to be undertaken.

General conclusions

A user friendly tool was successfully developed and validated to enable GHG emissions to be accurately determined at individual farm level. GHG emissions were calculated across seven dairy production systems in NI, with an average emission of 1.11 kg CO_2e/kg of milk produced. The range of GHG emissions calculated at each farm was relatively narrow (1.02 to 1.19 kg CO_2e/kg of milk produced) and is likely to increase as the GHG calculator is applied to a greater number of farming systems across NI. Uniquely, this tool used some assumptions specific to farming conditions in NI, based on recent research findings at AFBI. Enteric CH_4 emissions accounted for the majority of emissions on all farms (40% on average), followed by emissions from manure management and concentrate use.

Importantly, the calculator can also be used to explore the effects of mitigation strategies using experimental farming systems. The user friendly input tables and clear layout of the report enable farmers to explore and monitor the impact of GHG reduction strategies on the performance and carbon footprint of their dairy enterprise.

Wider application of the GHG calculator to a greater number of farming systems will enable more detailed statistical analyses to investigate further how different management and performance factors affect GHG emissions at the individual farm level. This will create opportunities to explore strategies to reduce GHG emissions at the individual farm level, whilst improving business efficiency at the same time.

Acknowledgements

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Appendix 1 – Data input tables within the AFBI calculator

Land/Crops | Livestock | Grazing/Forage | Fertiliser/Manure | Fuel/Electric | Land Use

Land Controlled Details (only include land attributable to the dairy enterprise)

Land Owned (ha):

Land Leased In (ha):

Land Let Out (ha):

Forage Offered During Grazing Period - Produced on Farm

			Total Quantity Offered (kg DM)					
Crop Name	Area (ha)	Yield (tonnes DM/ha)	Cows	Bulls	Heifers >2y	Heifers 1-2y	Heifers 6-12m	
Area of Grassland	0	0.0	0	0	0	0	0	Edit Delete
Grass Silage	0	0.0	0	0	0	0	0	Edit Delete
								Add Crop

Dry Matter Quick Calculator

Forage Offered During Indoor Period - Produced on Farm

			Total Quantity Offered (kg DM)					
Crop Name	Area (ha)	Yield (tonnes DM/ha)	Cows	Bulls	Heifers >2y	Heifers 1-2y	Heifers 6-12m	
								Add Crop

Dry Matter Quick Calculator

Forage Offered During Grazing Period - Bought Elsewhere

		Total Quantity Offered (kg DM)					
Crop Name	Quantity (kg/farm/yr)	Cows	Bulls	Heifers >2y	Heifers 1-2y	Heifers 6-12m	
							Add Crop

Dry Matter Quick Calculator

Forage Offered During Indoor Period - Bought Elsewhere

		Total Quantity Offered (kg DM)					
Crop Name	Quantity (kg/farm/yr)	Cows	Bulls	Heifers >2y	Heifers 1-2y	Heifers 6-12m	
							Add Crop

Dry Matter Quick Calculator

Land/Crops | Livestock | Grazing/Forage | Fertiliser/Manure | Fuel/Electric | Land Use

Dairy Livestock Numbers

Livestock Type	Average Number Per Year	
Dairy Cows	0	Calculate
Dairy Heifers (2 years +)	0	Calculate
Dairy Heifers (1 - 2 years)	0	Calculate
Dairy Heifers (6 - 12 mths)	0	Calculate
Dairy Bulls	0	Calculate

Dairy Livestock Live Weights

Dairy Cows and Bulls Live Weight

Livestock Type	Average Live Weight (kg)
Dairy Cows	625
Dairy Bulls	800

Dairy Heifers Live Weight

Livestock Type	Live Weight at Beginning (kg)	Live Weight at End (kg)
Dairy Heifers (2 years +)	580	620
Dairy Heifers (1 - 2 years)	310	580
Dairy Heifers (6 - 12 mths)	180	310

Milk Production

Total Annual Milk Sales:

Average Milk Fat (%): 4.00

Average Milk Protein (%): 3.20

Cows Calved

Livestock Type	Number Calved
Dairy Cows	
Dairy Heifers (2 years +)	
Dairy Heifers (1 - 2 years)	

Animal Exports

Animals Exported	No. Animals Exported	Live Weight
Bull calves		50
Heifers 0-1 year		175
Heifers 1-2 year		430
Heifers over 2 year		600
Cull Cows		620
Cull Mature Breeding Bulls		800

Land/Crops | Livestock | Grazing/Forage | Fertiliser/Manure | Fuel/Electric | Land Use

Months Grazing

Livestock Type	Months Grazing
Dairy Cows	6.0
Dairy Heifers (2 years +)	6.0
Dairy Heifers (1 - 2 years)	6.0
Dairy Heifers (6 - 12 mths)	6.0
Dairy Bulls	6.0

Concentrate Offered During Grazing Season (Fresh)

Livestock Type	Amount Fed (kg/year)	DM content (g/kg)	CP content (g/kg DM)	ME content (MJ/kg DM)	Ash content (g/kg DM)
Dairy Cows	0	860	181	12.8	70
Dairy Heifers (2 years +)	0	860	181	12.8	70
Dairy Heifers (1 - 2 years)	0	860	181	12.8	70
Dairy Heifers (6 - 12 mths)	0	860	181	12.8	70
Dairy Bulls	0	860	181	12.8	70

Fresh Concentrate Quick Calculator

Concentrate Offered During Indoor Period (Fresh)

Livestock Type	Amount Fed (kg/year)	DM content (g/kg)	CP content (g/kg DM)	ME content (MJ/kg DM)	Ash content (g/kg DM)
Dairy Cows	0	860	181	12.8	70
Dairy Heifers (2 years +)	0	860	181	12.8	70
Dairy Heifers (1 - 2 years)	0	860	181	12.8	70
Dairy Heifers (6 - 12 mths)	0	860	181	12.8	70
Dairy Bulls	0	860	181	12.8	70

Fresh Concentrate Quick Calculator

Forage Nutritive Values - Produced on Farm

	Grazing			Indoor			
Forage Name	CP Content (g/kg DM)	ME Content (MJ/kg DM)	Ash Content (g/kg DM)	CP Content (g/kg DM)	ME Content (MJ/kg DM)	Ash Content (g/kg DM)	
Grazed Grass	160	11.3	85	160	11.3	85	Edit Delete
Grass Silage	134	11.1	83	134	11.1	83	Edit Delete
							Add forage

(Warning - Please ensure nutritive values have been entered for any any forage offered)

Forage Nutritive Values - Bought Elsewhere

	Grazing			Indoor			
Forage Name	CP Content (g/kg DM)	ME Content (MJ/kg DM)	Ash Content (g/kg DM)	CP Content (g/kg DM)	ME Content (MJ/kg DM)	Ash Content (g/kg DM)	
							Add forage

(Warning - Please ensure nutritive values have been entered for any any forage offered)

Land/Crops | Livestock | Grazing/Forage | Fertiliser/Manure | Fuel/Electric | Land Use

Fertiliser Applications

Known Fertilisers

Fertiliser Type	Quantity of Product Applied (tonnes)	
		Add Fertiliser

Other Fertilisers

Fertiliser Name	Quantity of Product Applied	Nitrogen (% N)	Phosphate (% P_2O_5)	Potash (% K_2O)	
					Add Fertiliser

Emissions from Liming (only include land attributable to the dairy enterprise)

Annual Amount of Calcic Limestone ($CaCO_3$) used (kg/farm/year):

Annual amount of dolomite ($CaMg(CO_3)_2$ used (kg/farm/year):

Organic Manure Management Systems

Organic Manure Type	% of Manure Managed Under Each System	% of Manure Taken Away From Farms
Liquid slurry with natural crust over	50	0
Liquid slurry without natural crust over	0	0
Uncovered lagoon	0	0
Tank storage below slatted floor	50	0
Anaerobic digester	0	0
Farm Yard	0	0

Land/Crops | Livestock | Grazing/Forage | Fertiliser/Manure | Fuel/Electric | Land Use

Fuel Used

Fuel Type	Litres Per Year
Red Diesel	
White Diesel	
Heating Oil	
Petrol	

(See User Guide for Guidance)

Electricity Used

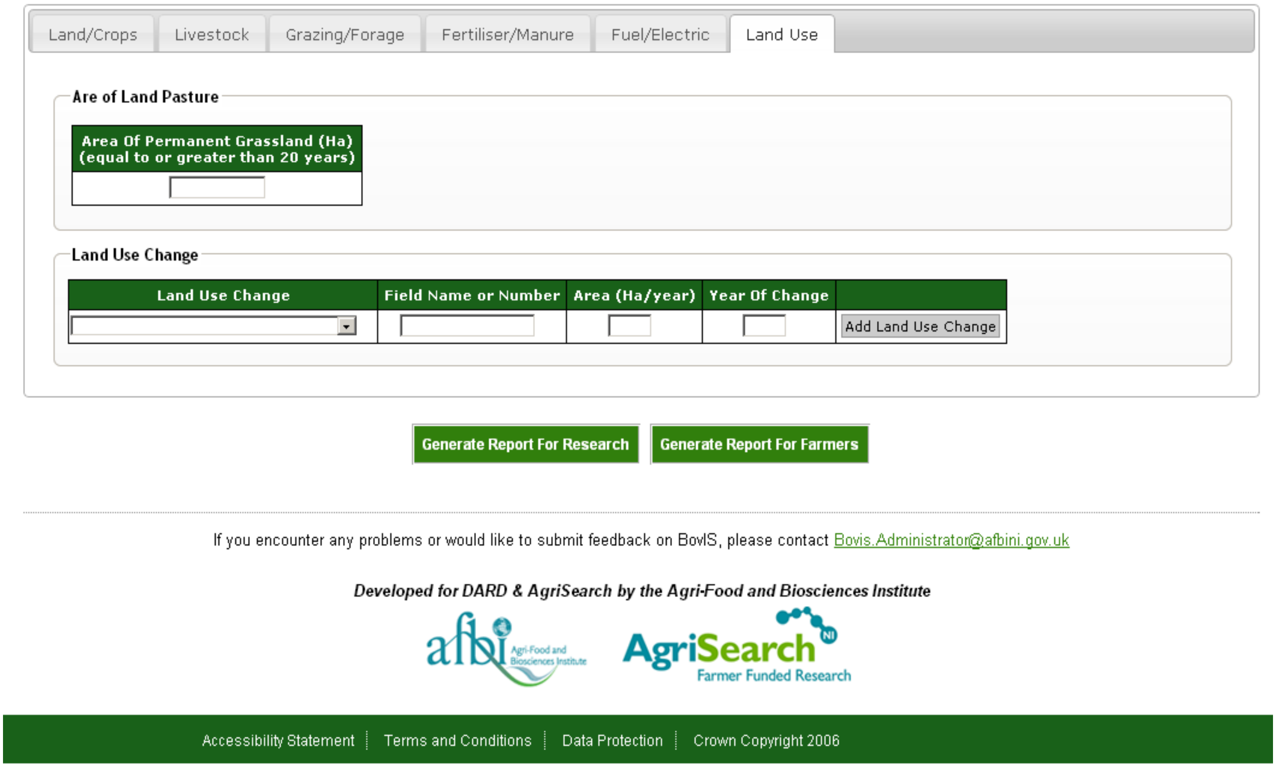
Electricity Used

(See User Guide for Guidance)

Contractor Operations

Contractor Operations	Area (Ha/year)	Average Haulage Distance (miles)	
			Add Contractor Operation

(See User Guide for Guidance)


Land/Crops
Livestock
Grazing/Forage
Fertiliser/Manure
Fuel/Electric
Land Use
Are of Land Pasture
Area Of Permanent Grassland (Ha) (equal to or greater than 20 years)
Land Use Change
Land Use Change
Field Name or Number
Area (Ha/year)
Year Of Change
Add Land Use Change
Generate Report For Research
Generate Report For Farmers
If you encounter any problems or would like to submit feedback on BovIS, please contact Bovis.Administrator@afbini.gov.uk
Developed for DARD & AgriSearch by the Agri-Food and Biosciences Institute
Agri-Food and Biosciences Institute
AgriSearch
Farmer Funded Research
Accessibility Statement
Terms and Conditions
Data Protection
Crown Copyright 2006

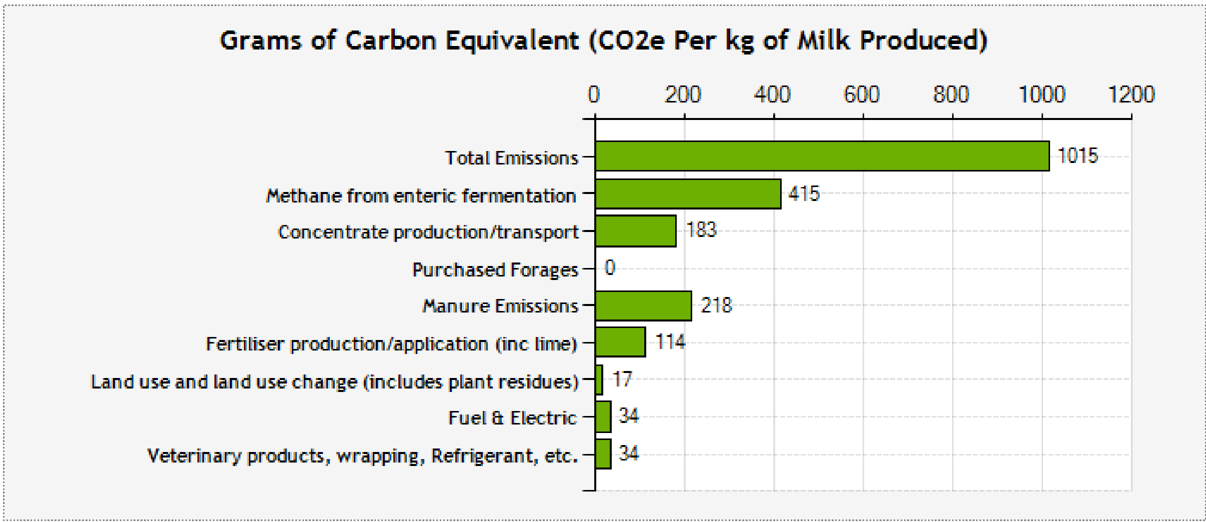
Appendix 2 – Example farmer report from the AFBI calculator

BovIS - Greenhouse Gas Calculators

Dairy Cattle

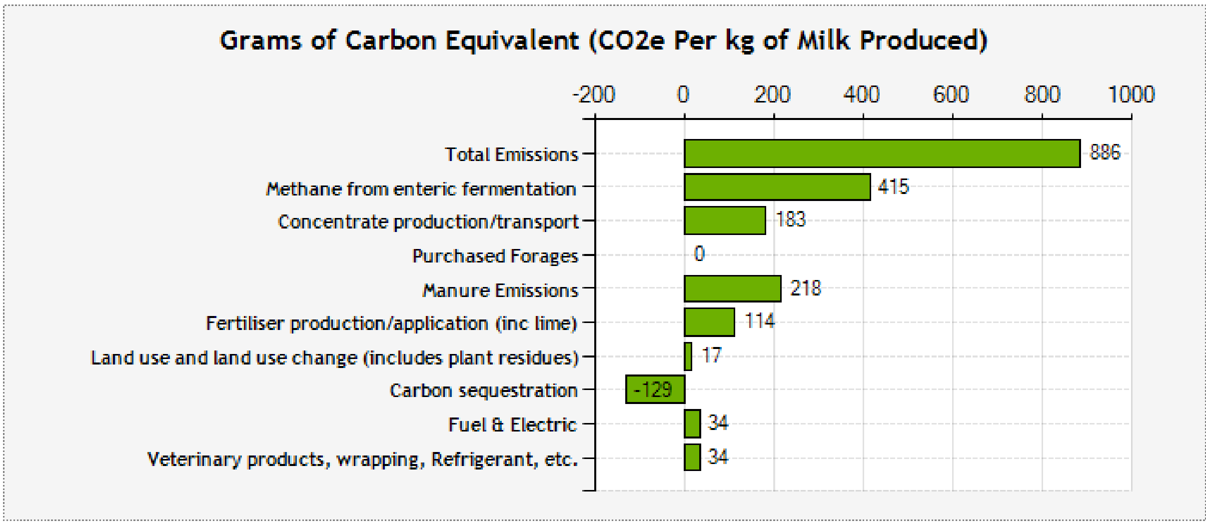
Emmissions By Source (Excluding Sequestration)

1. Carbon Emissions per kg of Milk Produced:1015 g CO_2e per kg of milk
2. Carbon Emissions per kg of Meat Produced:15.59 kg CO_2e per kg of meat (12.01% of total CO_2e emissions)



Emmissions By Source (Including Sequestration)

1. Carbon Emissions per kg of Milk Produced:886 g CO_2e per kg of milk
2. Carbon Emissions per kg of Meat Produced:13.61 kg CO_2e per kg of meat (12.01% of total CO_2e emissions)



Summary

Livestock

Dairy Cows:	153.0
Heifers:	76.7
Breeding Bulls:	0.0
Milk Sold (corrected):	1349927 kg
Yield per Cow:	8823 kg
Replacement Rate (excludes mortality):	23%
Average Concentrate Feed Rate:	0.31 kg conc/kg milk
Average Concentrate Feed Rate (inc heifers/breeding bulls):	0.33 kg conc/kg milk

Land Use

Grass:	77.0 ha
Forage Maize:	0.0 ha
Whole Crop Cereal:	0.0 ha
Other:	0.0 ha

Other

Milk from Forage:	2714 kg
Fertiliser Use:	55.00 tonnes
	13.75 tonnes N
	178.57 kg N/ha
Efficiency of Grass Utilisation:	9.371 tDM/ha
Liveweight exported:	28270 kg

Carbon Footprint

	CO_2e Emissions (exc Seq)	**CO_2e Emissions (inc Seq)**
Total Emmissions:	1369.87 tonnes	1195.75 tonnes
Total Emissions Relating to Milk Production:	8.953 tonnes per cow	7.815 tonnes per cow
	17.791 tonnes per ha	15.529 tonnes per ha
	1015 grams per kg milk	886 grams per kg milk

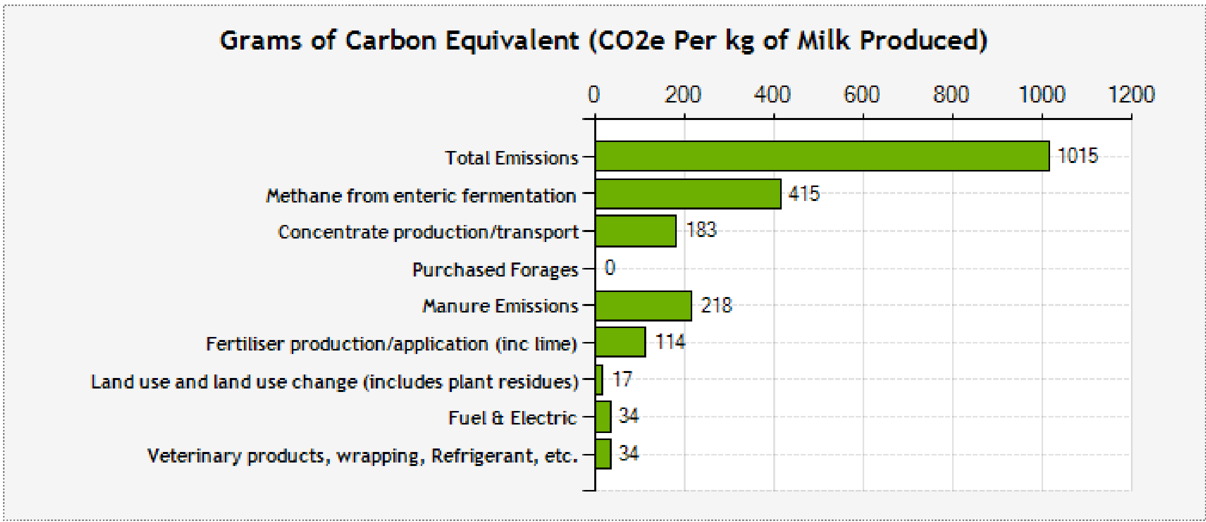
Appendix 3 – Example research report from the AFBI calculator

BovIS - Greenhouse Gas Calculators

Dairy Cattle - Report for Research

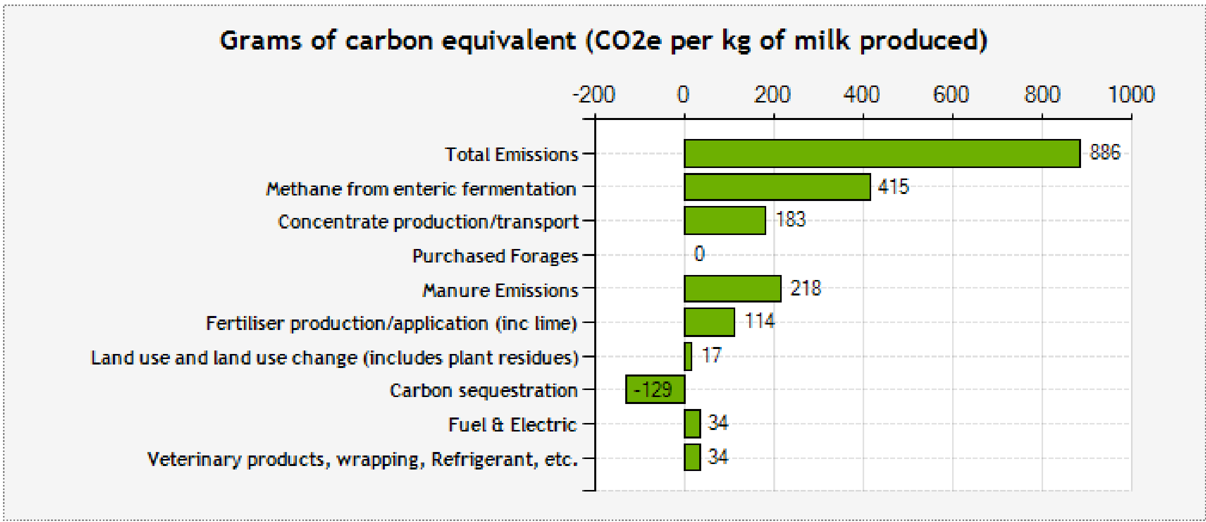
Excluding Sequestration

1. Carbon Emissions per kg of Milk Produced:1015 g CO_2e per kg of milk
2. Carbon Emissions per kg of Meat Produced:15.59 kg CO_2e per kg of meat (12.01% of total CO_2e emissions)



Including Sequestration

1. Carbon Emissions per kg of Milk Produced:886 g CO_2e per kg of milk
2. Carbon Emissions per kg of Meat Produced:13.61 kg CO_2e per kg of meat (12.01% of total CO_2e emissions)



Emissions by source (excluding sequestration)

- Total CO_2e emissions without CO_2 sequestration from the dairy enterprise (t/farm/year): 1556.9
- CO_2e emissions without CO_2 sequestration allocated to milk production (t/farm/year): 1369.9
- CO_2e emissions without CO_2 sequestration allocated to meat production (t/farm/year): 187.0
- CO_2e emission without CO_2 sequestration/land (t/ha): 20.2
- CO_2e emission without CO_2 sequestration/milk yield (g/kg): 1015
- CO_2e emission without CO_2 sequestration/calculated meat production (kg/kg): 15.6

Emissions by source (including sequestration)

- Total CO2e emissions with CO2 sequestration from the dairy enterprise (t/farm/year): 1359.0
- CO2e emissions with CO2 sequestration allocated to milk production (t/farm/year) : 1195.8
- CO2e emissions with CO2 sequestration allocated to meat production (t/farm/year): 163.2
- CO2e emission with CO2 sequestration/land (t/ha): 17.6
- CO2e emission with CO2 sequestration/milk yield (g/kg): 886
- CO2e emission with CO2 sequestration/calculated meat production (kg/kg): 13.6

Summary

		CO_2e/milk (g/kg)
Livestock & Feed	**Enteric fermentation**	415.1
	Concentrate production & transportation	182.7
	Respiration from forages bought elsewhere	0.1
Manure	**CH4 from Indoor manure storage**	81.3
	CH4 from Dung from grazing cattle	2.6
	N2O from Indoor manure storage	17.3
	N2O from Slurry spreading	45.8
	N2O from Dung/urine from grazing cattle	71.2
Fertiliser	**Inorganic fertiliser application**	55.6
	Fertiliser manufacture	55.2
	Application of lime & urea	3.1
Land	**Plant residues**	17.0
	Land use change	0.0
	Carbon sequestration	-129.0
Other	**Veterinary products, wrapping, Refrigerant, etc.**	33.7
	Fuel use for farming	17.3
	Electricity use for farming	16.8

Appendix 4 – User guide for the AFBI calculator

BovIS

Bovine Information System

Greenhouse Gas Calculator

Introduction

Welcome to the Bovine Information (BovIS) dairy greenhouse gas (GHG) calculator. Funded by DARD and AgriSearch, this application has been developed by AFBI to provide Northern Ireland dairy producers a facility to calculate the greenhouse gas emissions from their enterprises and investigate GHG reduction strategies.

Over 1000 equations form the basis of the dairy GHG calculator but the system has been designed in such a way to make it user friendly with minimal data input required. Research data from AFBI Hillsborough and national and international scientific studies have been used to develop a robust and an accurate calculator to predict GHG emissions.

The following guide steps out clearly how to:

1) Navigate through the application
2) Input data
3) Adjust default data
4) Generate a farmer GHG report
5) Interpret the report

Please send any questions or feedback on the BovIS GHG application to the following email address or contact your local CAFRE dairy adviser.

Yours sincerely

On behalf of the BovIS GHG development team
AFBI, Hillsborough Steven Morrison and Tianhai Yan
AFBI, Newforge Lane Mark Browne, Wylie McKinty and Erica Chisholm

Land and Crops page

Please enter the area of land owned, leased and rented out.

This is only land linked to the dairy enterprise (exclude land linked to other enterprises e.g. Sheep, beef etc).

Forages offered during indoor period – produced on farm

Under the Crop name select from the drop down list the first forage offered that is produced on the farm during the grazing period. This is most likely to be grass pasture.

Please enter the area of grassland (includes silage area) and the estimated annual yield (default yield will be shown).

With grassland there is **<u>no need</u>** to enter the quantity offered to each class of animal as it is calculated. Currently no option for grass silage buffer feeding is available but this will added in later versions.

Click Add Crop once you have completed data entry and if other forages are offered during the grazing season please repeat steps above. For all crops other that grassland, the quantity of forage offered (kg DM) to the class of livestock **<u>must be</u>** entered. To aid calculation a small quick calculator is available below the table from which values can be copied and pasted into the table.

Land and Crops page

Land/Crops | Livestock | Grazing/Forage | Fertiliser/Manure | Fuel/Electric | Land Use

Land Controlled Details (only include land attributable to the dairy enterprise)

Land Owned (ha): 107

Land Leased In (ha):

Land Let Out (ha):

Forage Offered During Grazing Period - Produced on Farm

Crop Name	Area (ha)	Yield (tonnes DM/ha)	Total Quantity Offered (kg DM) Cows	Bulls	Heifers >2y	Heifers 1-2y	Heifers 6-12m	
Area of Grassland	107	10.0	0	0	0	0	0	Edit Delete
								Add Crop

Dry Matter Quick Calculator

*Conversion   1 ha = 2.471 acres

Quick calculator

This quick calculator is available below many of the input tables to facilitate easy calculation of dietary inputs for the group of animals over the year.

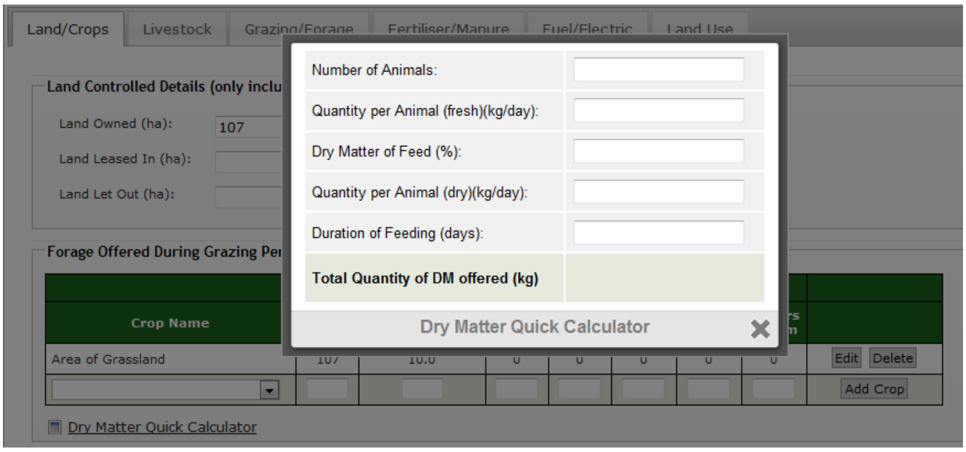
Enter the average number of animals in the group (see livestock page for the information).

Either enter the quantity of fresh forage offered per day per animal and the dry matter percentage of the forage (see nutritive value table) or enter the dry matter of forage offered per day per animal.

Enter the duration of feeding in days and the total quantity of forage offered to the group will be shown.

Handy tip: if you highlight and right click with your mouse on the calculated value of Total Quantity of DM offered and select copy you can then paste the value into the input table (right click when cursor is in the appropriate input box of main table).

Land and Crops page



Land and Crops page

Forage offered during indoor period – produced on farm

Repeat previous procedure for forages offered to cattle during the indoor period.

There is no need to re enter the area of grass grown and yield as you will have done this in the previous table. The quantity of grass silage fed will be calculated in the background therefore there is no need to input the quantity offered.

Click Add Crop if other forages are offered during the indoor period and repeat steps above. For all crops other that grass pasture, the quantity of forage offered (kg DM) to the class of livestock must be entered. To aid calculation a small quick calculator is available below the table from which values can be copied and pasted into the table.

Land and Crops page

Forage Offered During Indoor Period - Produced on Farm

			Total Quantity Offered (kg DM)					
Crop Name	Area (ha)	Yield (tonnes DM/ha)	Cows	Bulls	Heifers >2y	Heifers 1-2y	Heifers 6-12m	
Forage Maize	10	12.6	26000	0	0	0	0	Add Crop

Dry Matter Quick Calculator

*Conversion 1 ha = 2.471 acres

Land and Crops page

Forage offered during grazing period – bought elsewhere

Repeat previous procedure for forages offered to cattle during the grazing period except this time it is only for forages you have bought from elsewhere such as purchased maize silage, whole crop wheat etc.

Forage offered during indoor period – bought elsewhere

Repeat previous procedure except this time it is only for forages you have bought from elsewhere such as purchased maize silage, whole crop wheat etc.

Land and Crops page

Forage Offered During Grazing Period - Bought Elsewhere

		Total Quantity Offered (kg DM)					
Crop Name	Quantity (kg/farm/yr)	Cows	Bulls	Heifers >2y	Heifers 1-2y	Heifers 1y	
Grass Silage	0.0	0	0	0	0	0	Add Crop

Dry Matter Quick Calculator

Livestock and milk production page

Dairy livestock numbers

Please enter the average livestock count for each class of livestock. A calculator has been included which matches with the APHIS stock count tool under the Nitrates Stock Count. At present you will have to manually type in the livestock count data.

Dairy livestock live weights

Dairy cows and breeding bulls

Please enter the average live weight (kg) of dairy cows and dairy breeding bulls (defaults will be displayed).

Dairy heifer live weight

Please enter the live weight (kg) at the beginning of the period and the live weight at the end of the period for each heifer age range (defaults included).

Land/Crops | Livestock | Grazing/Forage | Fertiliser/Manure | Fuel/Electric | Land Use

Dairy Livestock Numbers

Livestock Type	Average Number Per Year	
Dairy Cows	120.2	Calculate
Dairy Heifers (2 years +)	23.0	Calculate
Dairy Heifers (1 - 2 years)	59.0	Calculate
Dairy Heifers (6 - 12 mths)	50.0	Calculate
Dairy Bulls	3.0	Calculate

Dairy Livestock Live Weights

Dairy Cows and Bulls Live Weight

Livestock Type	Average Live Weight (kg)
Dairy Cows	620
Dairy Bulls	800

Dairy Heifers Live Weight

Livestock Type	Live Weight at Beginning (kg)	Live Weight at End (kg)
Dairy Heifers (2 years +)	550	620
Dairy Heifers (1 - 2 years)	330	550
Dairy Heifers (6 - 12 mths)	180	330

Livestock and milk production page

Milk production

Please enter the total annual milk sales (L/yr) and the average milk quality (fat and protein %).

Cows calved

Please enter the number of cows and heifers that calved during the reporting period.

Animal exports

Please enter the number of animals for each class that have left the farm (excludes deaths) during the reporting period and the average live weight (default weights can be used). If no value is entered the calculator will use stored default weight values.

The calculator will assume an export rate of 20% for dairy cows and 50% for calves born if no value is entered. All bull calves should be immediately transferred to a beef enterprise at birth for calculation purposes.

Livestock and milk production page

Milk Production

Total Annual Milk Sales: 925000

Average Milk Fat (%): 4.00

Average Milk Protein (%): 3.20

Cows Calved

Livestock Type	Number Calved
Dairy Cows	120
Dairy Heifers (2 years +)	26
Dairy Heifers (1 - 2 years)	20

Animal Exports

Animals Exported	No. Animals Exported	Live Weight
Bull calves	83	50
Heifers 0-1 year	30	175
Heifers 1-2 year	0	430
Heifers over 2 year	0	600
Cull Cows	25	620
Cull Mature Breeding Bulls	0	800

Grazing/Forage page

Months grazing

Please enter the number of months grazing. Please factor in if partial confinement systems are used (e.g. Grazing by day, housed at night). Example

5 months full time grazing
1 month ½ day grazing
= 5.25 months grazing

Concentrate offered during the grazing season (fresh basis)

Please enter the amount of concentrate fed to the group of animals during grazing (quick calculator available below the table). If required please edit the default concentrate quality values on the right hand side of the table.

Nutritive quality parameter	Description	Example
DM content (g/kg)	Dry matter	20% is the same as 200 g/kg
CP content (g/kg DM)	Crude protein	18% is the same as 180 g/kg DM
ME content (MJ/kg DM)	Metabolisable energy	
Ash content (g/kg DM)	Ash	5% is the same as 50 g/kg DM

* Ensure values are expressed on a DM basis e.g. if dairy meal supplied at 18% CP (fresh basis) and the meal is approximately 87% dry matter then CP on a dry basis is 18/(87/100)=20.7g CP/kg DM

Grazing/Forage page

Land/Crops | Livestock | Grazing/Forage | Fertiliser/Manure | Fuel/Electric | Land Use

Months on Grazing

Livestock Type	Months of Grazing
Dairy Cows	5.5
Dairy Heifers (2 years +)	6.0
Dairy Heifers (1 - 2 years)	6.0
Dairy Heifers (6 - 12 mths)	6.0
Dairy Bulls	6.0

Concentrate Offered During Grazing Season (Fresh)

Livestock Type	Amount Fed (kg/year)	DM content (g/kg)	CP content (g/kg DM)	ME content (MJ/kg DM)	Ash content (g/kg DM)
Dairy Cows	130968	860	181	12.8	70
Dairy Heifers (2 years +)	0	860	181	12.8	70
Dairy Heifers (1 - 2 years)	0	860	181	12.8	70
Dairy Heifers (6 - 12 mths)	3350	860	181	12.8	70
Dairy Bulls	0	860	181	12.8	70

Fresh Concentrate Quick Calculator

Grazing/Forage page

Concentrate offered during the <u>indoor period</u> (fresh basis)

Please enter the amount of concentrate fed to the group of animals during the indoor period (quick calculator available below the table). If required please edit the default concentrate quality values on the right hand side of the table.

Forage nutritive value – Produced on farm

For every home grown forage you have entered as being offered to cattle in the earlier table a forage nutritive quality must be entered in this table. Default values are provided but can be altered for home grown forages offered during the grazing and indoor periods. After the quality has been entered select 'add forage'.

Forage nutritive value – Bought elsewhere

For every purchased forage you have entered as being offered to cattle in the earlier table a forage nutritive quality must be entered in this table. Default values are provided but can be altered for bought forages offered during the grazing and indoor periods. After the quality has been entered select 'add forage'.

Grazing/Forage page

Concentrate Offered During Indoor Period (Fresh)

Livestock Type	Amount Fed (kg/year)	DM content (g/kg)	CP content (g/kg DM)	ME content (MJ/kg DM)	Ash content (g/kg DM)
Dairy Cows	154768	860	181	12.8	70
Dairy Heifers (2 years +)	0	860	181	12.8	70
Dairy Heifers (1 - 2 years)	8850	860	181	12.8	70
Dairy Heifers (6 - 12 mths)	10000	860	181	12.8	70
Dairy Bulls	0	860	181	12.8	70

Fresh Concentrate Quick Calculator

Forage Nutritive Values - Produced on Farm

	Grazing			Indoor			
Forage Name	CP Content (g/kg DM)	ME Content (MJ/kg DM)	Ash Content (g/kg DM)	CP Content (g/kg DM)	ME Content (MJ/kg DM)	Ash Content (g/kg DM)	
Grazed Grass	160	11.3	85	160	11.3	85	Edit Delete
Grass Silage	119	10.9	80	119	10.9	80	Edit Delete
							Add forage

Forage Nutritive Values - Bought Elsewhere

	Grazing			Indoor			
Forage Name	CP Content (g/kg DM)	ME Content (MJ/kg DM)	Ash Content (g/kg DM)	CP Content (g/kg DM)	ME Content (MJ/kg DM)	Ash Content (g/kg DM)	
							Add forage

Fertiliser and manure page

Fertiliser applications

From the drop down list please select the fertiliser applied to land associated with the dairy enterprise only. Enter the quantity applied and select 'add fertiliser.' This can be repeated if more than one type of fertiliser has been used.

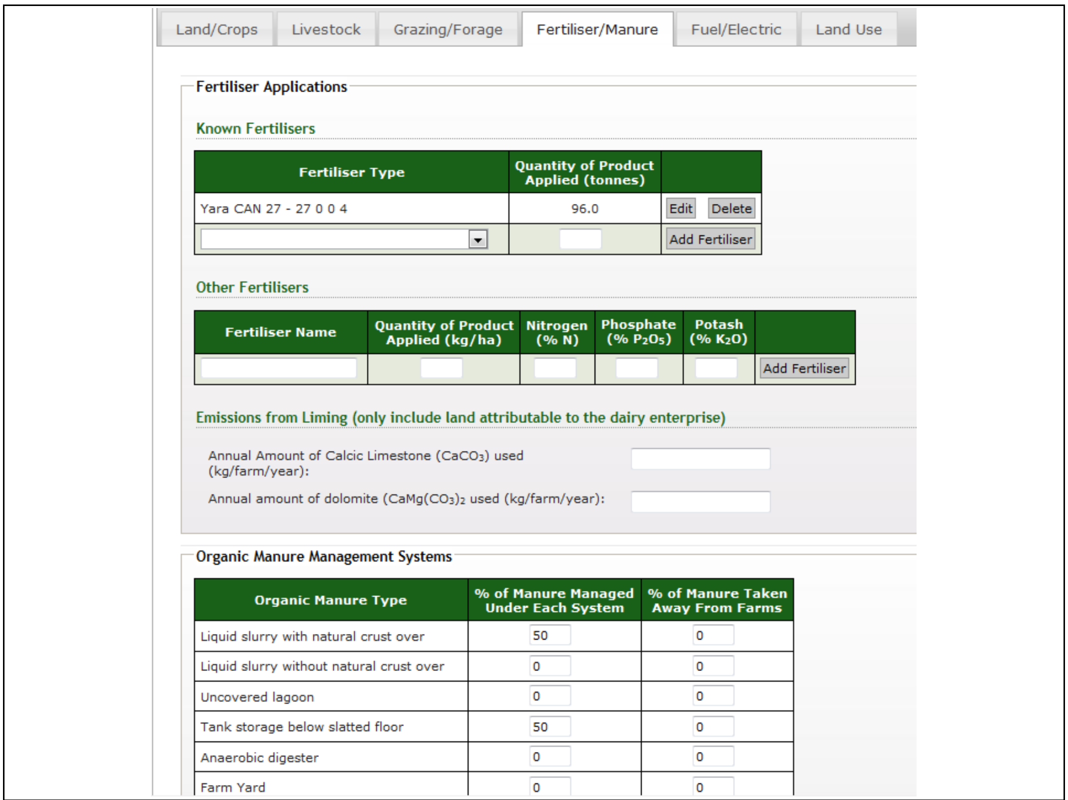
If the fertiliser used is not available in the list a custom fertiliser can be created within the 'other fertiliser' table.

Lime applications

Please enter the quantity of lime (two types of lime available to select from) applied to land associated with the dairy enterprise only.

Organic manure management systems

Please enter the percentage of manure that is managed under each system and also enter the percentage of any manure that is exported off the dairy enterprise (e.g. may be exported to beef enterprise or other farms).



Land/Crops | Livestock | Grazing/Forage | Fertiliser/Manure | Fuel/Electric | Land Use

Fertiliser Applications

Known Fertilisers

Fertiliser Type	Quantity of Product Applied (tonnes)	
Yara CAN 27 - 27 0 0 4	96.0	Edit Delete
		Add Fertiliser

Other Fertilisers

Fertiliser Name	Quantity of Product Applied (kg/ha)	Nitrogen (% N)	Phosphate (% P_2O_5)	Potash (% K_2O)	
					Add Fertiliser

Emissions from Liming (only include land attributable to the dairy enterprise)

Annual Amount of Calcic Limestone ($CaCO_3$) used (kg/farm/year):

Annual amount of dolomite ($CaMg(CO_3)_2$ used (kg/farm/year):

Organic Manure Management Systems

Organic Manure Type	% of Manure Managed Under Each System	% of Manure Taken Away From Farms
Liquid slurry with natural crust over	50	0
Liquid slurry without natural crust over	0	0
Uncovered lagoon	0	0
Tank storage below slatted floor	50	0
Anaerobic digester	0	0
Farm Yard	0	0

Fuel and electric page

Fuel used

If you know the quantity of **ALL** fuel used within the dairy enterprise (red/white diesel, heating oil and petrol) please enter in the appropriate box. If **UNSURE OF ALL OR ANY** of the values **LEAVE BLANK** and defaults will be generated by the calculator.

If you have left the fuel used box **blank** (i.e. not inputted all the values) then **ignore** the contractor operations section.

Electricity used

Please enter the quantity of electricity used (kwh) within the dairy enterprise only or leave blank and defaults will be generated by the calculator.

Contractor operations

If fuel use table has been left blank **and** contractors use diesel from your farm diesel tanks then **ignore** this table otherwise add detail to the contractor operations input table.

Select the appropriate contracting operation, enter the area involved (note if 2 or 3 cut silage is selected it is the total area cut i.e. 100 acres 1st cut+80 acres second + 30 acres 3rd cut = 210 acres). Enter the average haulage distance where appropriate so diesel use can be calculated.

Fuel and electric page

Land/Crops | Livestock | Grazing/Forage | Fertiliser/Manure | Fuel/Electric | Land Use

Fuel Used

Fuel Type	Litres Per Year
Red Diesel	0
White Diesel	0
Heating Oil	0
Petrol	0

(See User Guide for Guidance)

Electricity Used

Electricity Used

(See User Guide for Guidance)

Contractor Operations

Contractor Operations	Area (Ha/year)	Average Haulage Distance (miles)	
			Add Contractor Operation

(See User Guide for Guidance)

*Conversion 1 ha = 2.471 acres

Land use and land use change page

Area of permanent grassland

Input the area of grassland (grazing plus silage) linked to the dairy enterprise that has been in permanent grass for equal to or greater than 20 years (this includes areas that have been grassland reseeds).

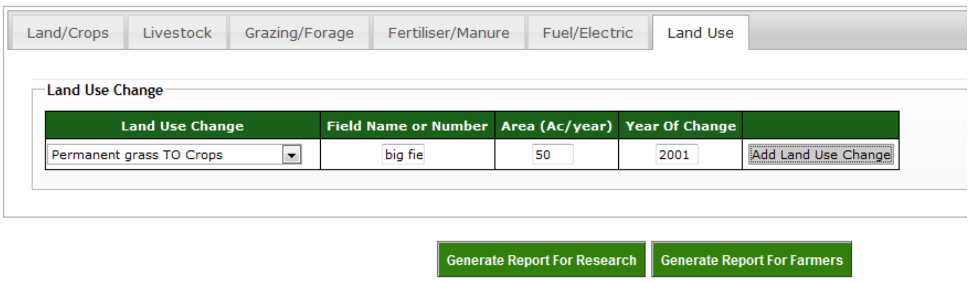
Land use change

When land is converted, for example from grass to cereals, greenhouse gases are released which are accounted for over a 20 year period. If the fields that have been used in the current year (linked to dairy enterprise only) have been converted from a previous use in the past 20 years they must be accounted for.

Select 'land use change' type and enter the field (can have multiple fields for the same land use type change). Enter the year that the **most recent** change occurred within the 20 year time period. Click 'add land use change' button. If unsure of the land use change type/year for example with rented land then assume no land use change.

Example scenarios – grassland converted to production of forage maize within the calculator would be permanent grassland to crops; grassland that is continually in a rotation with crops i.e. never more than 5 years in grass within the calculator would be temporary grassland to cropland and vice versa.

Land use and land use change page



*Conversion 1 ha = 2.471 acres

Farmer report

Generate a report

Click 'generate report for farmers' to display a GHG emissions report for your dairy enterprise

The GHG emissions report indicates the overall level of GHG emissions per kg of milk produced from your farm and the main sources of these emissions. Through knowing and understanding the emissions on your farm you can explore and monitor the impact of GHG reduction strategies.

Carbon emissions per kg of milk produced (excluding sequestration)

Within agriculture systems there are three main GHGs: nitrous oxide, carbon dioxide and methane. Each of the gases has to be weighted based on their differing global warming potential. Methane and nitrous oxide are 25x and 298x more potent than carbon dioxide respectively. All the values shown in the GHG emissions report are expressed as CO_2e (carbon dioxide equivalents).

Because dairy systems also produce meat (or livestock sales) a proportion of the dairy emissions must be attributed to meat production based on the animal number/weights exported from your farm.

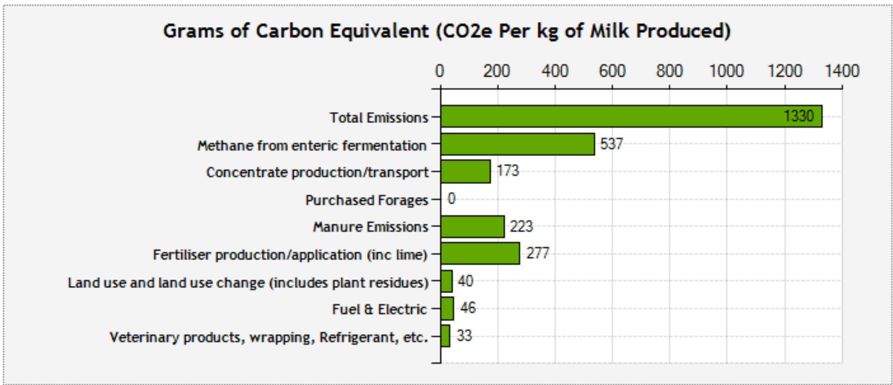
The graph within the report shows the main sources of GHG emissions per unit of milk output on your farm.

Farmer report

Emmissions By Source (Excluding Sequestration)

Carbon Emissions per kg of Milk Produced: 1330 g CO_2e per kg of milk

Carbon Emissions per kg of Meat Produced: 20.79 kg CO_2e per kg of milk (14.98% of total CO_2e emissions)



Farmer report

Carbon emissions per kg of milk produced (<u>including sequestration</u>)

Agriculture soils have the ability to sequester or lock in carbon produced within agriculture systems. The amount of carbon sequestration can be affected by many factors such as soil type, crop type, land management etc. The complexity of soil carbon sequestration and the fact that much of the carbon sequestered can be lost if the land use is changed (e.g. grassland ploughed up and converted to cereals) means that accounting for sequestration in GHG calculators is very difficult. Accredited GHG calculators must show emissions excluding sequestration but can additionally show the effect of sequestration.

Within the BovIS GHG calculator, carbon sequestration rates from permanent grassland are based on the values recorded within AFBI studies. ‘These data were obtained from an experiment on a slightly gleyed, sandy clay-loam soil extending over 40 years in which perennial ryegrass swards received a range of slurry treatments and were cut three times per annum. Accumulation of carbon was measured in the top 15 cm of soil. Data were adjusted to assume a total available N application of 100 kg N/ha/annum’.

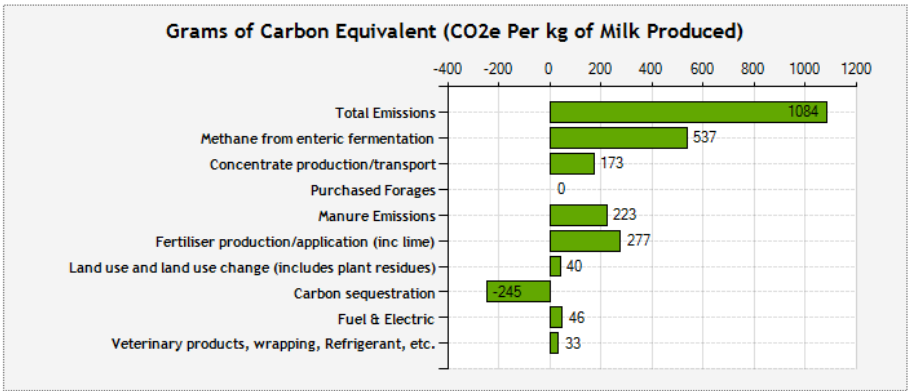
As and when the science of soil sequestration develops the BovIS GHG calculator will be updated accordingly.

Farmer report

Emmissions By Source (Including Sequestration)

Carbon Emissions per kg of Milk Produced: 1084 g CO_2e per kg of milk

Carbon Emissions per kg of Meat Produced: 16.96 kg CO_2e per kg of milk (14.98% of total CO_2e emissions)



Farmer report – summary info

Livestock

A small summary table has been included recapping what information has been inputted into the calculator. A replacement rate has been calculated based on the number of cull cows divided by the maximum number of dairy cows from the input table.

Land use

A small summary table has been included recapping what land/crop information has been inputted into the calculator.

Other

Based on the information inputted into the calculator a number of efficiency indicators have been calculated including milk from forage and efficiency of grass utilisation.

For assistance in interpreting these key performance indicators please contact you local CAFRE dairying adviser.

Livestock

Dairy Cows:	136.0
Heifers:	132.0
Breeding Bulls:	3.0
Milk Sold (corrected):	952994 kg
Yield per Cow:	7007 kg
Replacement Rate (excludes mortality):	0.29%
Average Concentrate Feed Rate:	0.30 kg conc/kg milk
Average Concentrate Feed Rate (inc heifers/breeding bulls):	0.32 kg conc/kg milk

Land Use

Grass:	107.0 ha
Forage Maize:	0.0 ha
Whole Crop Cereal:	0.0 ha
Other:	0.0 ha

Other

Milk from Forage:	2341 kg
Fertiliser Use:	96.00 tonnes
	25.92 tonnes N
	242.24 kg N/ha
Efficiency of Grass Utilisation:	7.307 tDM/ha
Liveweight exported:	29100 kg

Farmer report – carbon footprint

A small summary table showing the total GHG emissions from the dairy enterprise (with and without sequestration) has been included. Emissions are shown per kg of milk, per hectare and per cow.

Within the current version of the BovIS GHG calculator no data is stored or retained by AFBI therefore it is advisable that you print off or save your report.

Farmer report –carbon footprint

Carbon Footprint

	CO_2e Emissions (exc Seq)	CO_2e Emissions (inc Seq)
Total Emmissions:	1261.01 tonnes	1034.18 tonnes
Total Emissions Relating to Milk Production:	9.272 tonnes per cow	7.604 tonnes per cow
	11.785 tonnes per ha	9.665 tonnes per ha
	1323 grams per kg milk	1085 grams per kg milk

Dairy greenhouse gas reduction strategies

Overall strategy	Examples of methods to achieve strategy
Improving feed efficiency	batching dairy cattle; balanced diet formulation; increased efficiency of grazing
Nutrient management planning	matching nutrient application to crop needs; correcting soil pH; nutrient management plans
On-farm energy efficiency	efficient milking & milk storage equipment; alternative energy sources; maintenance of agriculture equipment such as tractors and machinery
Timing and application of slurry	nutrient management plans; timing slurry application for maximum N uptake/reduced wastage; low emission spreading techniques such as trailing shoe
Grass / clover production	use of legume crops to reduce fertiliser N requirements; maximising grass yield and efficiency of utilisation
Genetic improvement	long term breeding strategy to produce cattle with increased longevity, improved fertility and reduced susceptibility to mastitis and lameness whilst still maintaining or improving milk output per unit of feed intake; use of PLI breeding index
Efficient rearing of dairy herd replacements	Targeted rearing of heifers to calve at 24 months of age results in: reduced cattle on the farm; reduced feed inputs/land requirements; reduced non productive days; with research having shown no negative effects on longevity, milk yield or fertility
Improved fertility	Balanced and targeted nutrition; improved heat detection; breeding plans; benchmarking performance
Improved animal health/welfare	Improved hygiene; health plans; vaccination plans; disease eradication programmes; animal breeding

For more information on the Northern Ireland Greenhouse Gas Reduction Strategy and Action Plan see the DARD website
DARD - Efficient Farming cuts Greenhouse Gases

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