



## **Greenhouse gas emissions on British dairy farms**

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DairyCo carbon foot printing study: Year Three (2012-2013)

**Report prepared for DairyCo**

**May 2014**



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## Executive summary

The Climate Change Act requires a national greenhouse gas (GHG) reduction of 80% from 1990 levels, across the UK economy by 2050. Agriculture must play its part, delivering an interim 11% reduction on 2008 emission levels by 2020.

Agricultural GHG emissions include methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), and carbon dioxide (CO<sub>2</sub>). In terms of global warming potential (GWP), methane and nitrous oxide respectively, are approximately 23 and 297 times more potent as greenhouse gases than carbon dioxide. Methane is produced mainly from enteric fermentation by ruminants and from animal manures; nitrous oxide is lost following fertiliser and manure application, carbon dioxide is emitted as a by-product of fertiliser manufacturing and the burning of other sources of fossil fuels.

A three-year investigation into the carbon footprint of British milk was completed in 2013. The main objectives of the study were, to:-

- provide a robust, Carbon Trust verified, average carbon foot print for GB milk
- identify hotspots for GHG emissions at farm level
- provide participant farmers with a carbon footprint for milk on their farm, highlighting current performance and potential opportunities for efficient carbon management
- verify strategies to improve carbon efficiency in dairy farming

A sample of 415 farms reflective of the British dairy industry was recruited to the survey in 2010. Each year, farms which had to leave the survey during the period of the study, were replaced by others with broadly similar characteristics, so as to retain the integrity of the sample. A core of 305 farms completed all three years of the survey - a retention rate of 73%. Over all three years, 1,245 individual farm assessments contributed to the study.

The report base-lined the carbon foot print of British milk up to the farm gate, which typically represents over 80% of the total carbon footprint of liquid milk. All emissions were converted into grams CO<sub>2</sub> equivalent, and carbon footprint expressed as grams of CO<sub>2</sub> equivalent per litre of fat corrected milk. The weighted average footprint over the three years of the study was 1,232 (g CO<sub>2</sub>e/litre), which is broadly comparable to international published figures. For the annual sample of 415 farms, the average foot print (g CO<sub>2</sub>e/litre of fat corrected milk) was 1,293, 1,227 and 1,177, for years 1 to 3 respectively - an overall reduction of 9.0% over the period studied. This was consistent with the core sample of 305 farms which recorded average footprints of 1,287, 1,220, and 1,183 g CO<sub>2</sub>e/litre for years 1 to 3 respectively – a reduction of 8.1% for the period overall.

The corresponding figures (g CO<sub>2</sub>e/litre of fat and protein corrected milk) for the annual sample of 415 farms, calculated each year according to the method of the International Dairy Federation were 1,327, 1,270 and 1,252 respectively, indicating good consistency between both methodologies.

Of the total GHG emitted, on average, methane accounted for 41%, carbon dioxide 44% and nitrous oxide 15%. The main sources were enteric emissions (38%), methane from manures (6%), nitrous oxide from manures and artificial fertilisers (15%), fertiliser production (7%), feed production (25%), fuel (3%), electricity (3%) and other e.g. lime, bedding (2%).

No one farm type was more carbon efficient than another. Carbon foot print was mainly a function of the individual management applied, and level of performance achieved. The wide range in carbon footprint recorded, illustrates the potential for improvement, by focussing on key efficiency measures - milk output per cow, feed conversion, fertiliser and manure utilisation, herd replacement rate, energy and fuel consumption.

## Objectives of the Study

The objectives of the study were to:-

- Provide a Carbon Trust verified average carbon footprint figure for GB milk production based on actual farm data collected over a three-year period
- Benchmark industry performance, in order to measure year-on-year improvement
- Provide each participating farmer with a carbon footprint figure, identifying 'hot spots' of carbon emissions and how these may be reduced
- Record any mitigation or abatement practices which reduce carbon footprint
- Calculate separately, carbon footprint according to International Dairy Federation (IDF) methodology
- Present information from a range of participating farms as specific case studies.

## Study design

### Sampling

Initially 415 farms were recruited to the study, reflecting a diversity of dairy production systems in England (70%), Scotland (15%) and Wales (15%). The overall sample size was maintained by the replacement of farms which left the study, for a variety of reasons - 67 and 43 farms in years 1 and 2 respectively. Replacement farms were individually selected in order to maintain the balance of herd size, system type and regional distribution. A core of 305 farms completed all three years. A total of 1245 individual carbon footprints were collected over the duration of the study.

**Figure 1. Geographical distribution – 415 participating farms**



### Data collection

Participating farmers granted permission for the analysis and anonymous reporting of the data. On-farm data collection was completed by trained E-CO<sub>2</sub> assessors. Farm specific data, needed to calculate a carbon footprint, was classified broadly into five categories:

- Livestock and livestock management;
- Milk output and composition;
- Feed use;
- Fertiliser use; and
- Manure management.

Data were checked against livestock movement records, farm accounts, and where appropriate, outputs of herd management software. A system of grading (1 High: 5 Low) was used to gauge the reliability of the data collected. During year 3 assessments, 92% of the 415 farms scored 1-3; a further improvement on previous years. This suggests participants were becoming increasingly comfortable with the carbon foot printing process, including preparation of relevant documentation prior to the assessment.

## **Data analysis**

In order to calculate a carbon footprint for each farm, the data were run through a commercially available, PAS2050-compliant calculator. Through the carbon foot printing process, operations associated with the dairy are effectively 'split out' and emissions are appropriately allocated to the functional unit: grams CO<sub>2</sub> equivalent (CO<sub>2</sub>e) per litre of milk produced. Credits are given for transfers off farm including, but not limited to, manure exports and animals sold. Likewise, movements on to the farm, such as imported manure or animals purchased, incur a 'carbon cost' which is ultimately applied to the functional unit to determine a farm's carbon footprint. For example, this approach ensures a replacement system based on home-rearing, will have a comparable carbon footprint to that where animals are managed in a flying herd.

## **Carbon Trust verification**

Carbon foot printing procedures, data collection, farm carbon results, data analysis and reporting have been verified by Carbon Trust Certification as consistent with IPCC methodology and PAS 2050 for carbon foot printing. However, the average carbon footprint produced from this work cannot be considered to be in full conformity with PAS2050:2008 as it does not meet clause 4.3 on product differentiation i.e. the carbon footprint for this study covers a milk pool spread across a number of supply chains, which are outside the direct control of DairyCo.

## Results

No changes to the carbon foot printing model occurred between year 2 and year 3, and no revision of previous results was necessary.

### Herd size, average yield, and total milk sold

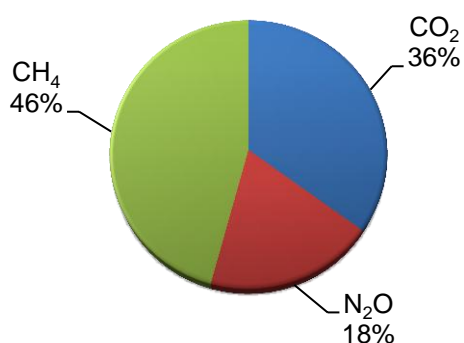
Milk yields and total volumes sold are reported as 4% butterfat-corrected milk throughout this report, unless otherwise stated.

**Table 1. Descriptive statistics – 415 dairy farms**

	Herd size (cows)		Average yield (litres)		Total milk sold (million litres)	
	Mean	Range	Mean	Range	Mean	Range
<b>Year 1</b>	180	25-1037	7,490	2,659-10,966	1.360	0.079-8.173
<b>Year 2</b>	181	28-9950	7,616	2,337-11,139	1.371	0.092-7.950
<b>Year 3</b>	183	25-981	7,735	2195-1018	1.409	0.119-7.835
<b>3-year mean</b>	181		7,614		1.380	

### Distribution of Greenhouse Gas emissions

**Figure 2. Distribution of emissions by gas**



There are three main types of agriculturally related greenhouse gas emissions: nitrous oxide (N<sub>2</sub>O), methane (CH<sub>4</sub>), and carbon dioxide (CO<sub>2</sub>). The greenhouse gas potency of the three gases is different; meaning that to calculate a carbon footprint, a carbon dioxide equivalent (CO<sub>2</sub>e) is calculated using a weighting factor for both methane and nitrous oxide. The sum of these values, and carbon dioxide produced, becomes the farm's total carbon emissions. In year 3, 46% of emissions could be attributed to methane, 18% to nitrous oxide, and 36% to carbon dioxide, for the average farm.

**Figure 3. Distribution of emissions by source**

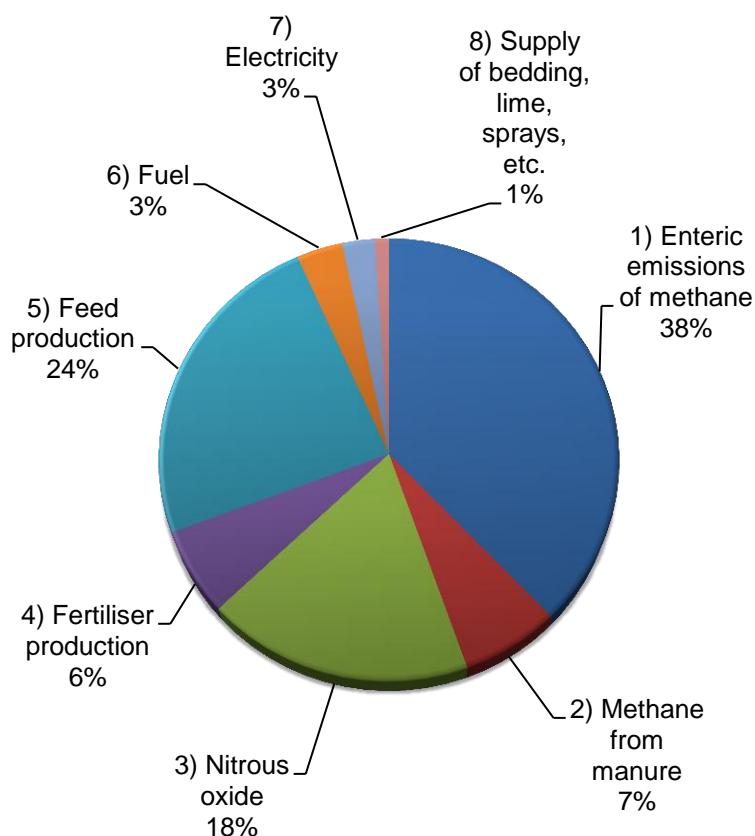


Figure 3 gives the proportion each source of emission contributes towards overall carbon footprint in year 3. The relative ranking of each source remained unchanged, and no source varied by more than 1% compared to the previous year. Nitrous oxide is mainly emitted from the breakdown of fertiliser, animal manures, sewage sludge (if used) and crop residues, while methane primarily arises from enteric emissions due to rumen fermentation, and to a lesser extent, from manure management. Carbon dioxide is attributed to electricity, fertiliser and spray production, lime, straw, bedding, and animal feed production, as well as fuel use.

## Carbon footprint

The average carbon footprint for year 3 (2012/2013), calculated using E-CO<sub>2</sub>'s Carbon Trust certified dairy model, is 1,177 g CO<sub>2</sub>e/l of 4% fat-corrected milk. This weighted average was calculated by multiplying the emissions per litre for each farm by total milk output. This provided total emissions per farm, which was then divided by total milk produced for all 415 participating farms. Carbon footprint data for each of the three years studied are given in Table 2. The 3-year, weighted-average carbon footprint is 1,232 g CO<sub>2</sub>e/l year.

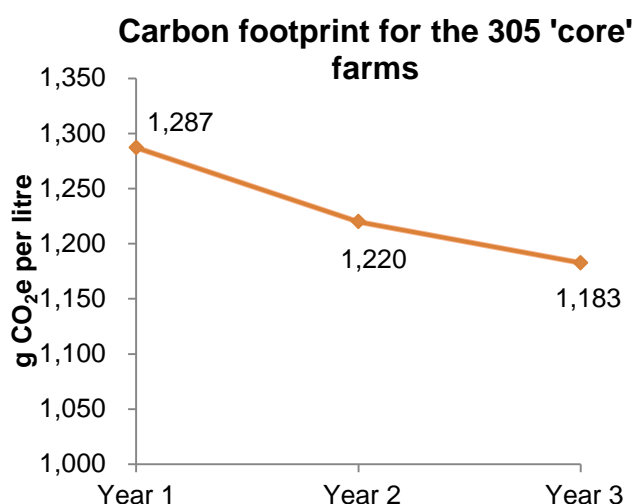
**Table 2. Carbon footprint – 415 farms (g CO<sub>2</sub>e/l)**

	Year 1	Year 2	Year 3
<b>Mean</b>	1,293	1,227	1,177
<b>Standard Error</b>	13	10	9.3
<b>Median</b>	1,245	1,191	1,149
<b>Mode</b>	1,008	1,114	1,012
<b>Standard Deviation</b>	262	211	189
<b>Skewness</b>	1.7	1.4	1.2
<b>Range</b>	1,929	1,336	1,239
<b>Minimum</b>	828	820	847
<b>Maximum</b>	2,757	2,157	2,085

A weighted average carbon footprint was also calculated for the 305 'core' farms over the three years of the study (Table 3). The average carbon footprint reduced by 3.1%, from 1,220 g CO<sub>2</sub>e/l in year 2 to 1,182 g CO<sub>2</sub>e/l in year 3.

**Table 3. Three-year carbon trend – 305 farms (g CO<sub>2</sub>e/l)**

	Year 1 – 305 Farms	Year 2 – 305 Farms	Year 3 – 305 Farms
<b>Mean</b>	1,287	1,220	1,183
<b>Standard Error</b>	15	12	11
<b>Median</b>	1,252	1,188	1,155
<b>Standard Deviation</b>	255	210	195
<b>Skewness</b>	1.4	1.2	1.2
<b>Range</b>	1,591	1,282	1,239
<b>Minimum</b>	828	859	847
<b>Maximum</b>	2,420	2,141	2,085



A general reduction is seen in the average carbon footprint when comparing the 305 core farms over three years of this study; confirming that the reduction in carbon footprint for the full set of 415 farms is not the result of newly introduced farms having lower emissions. The average carbon footprint decreased by 8.1% from 1,287 g CO<sub>2</sub>e/l year 1 to 1,183 g CO<sub>2</sub>e/l year 3. There was a good correlation between carbon footprint for the core 305 farms (1,183 g CO<sub>2</sub>e/l) in Year 3, and the weighted average for the 110 replacement

farms (1,164 g CO<sub>2</sub>e/l) entering the study at the end of Years 1 and 2.

### Carbon footprint and fat and protein corrected milk

Data were also recalculated on the basis of fat and protein corrected milk (FPCM), and compared to results expressed on a 4% fat corrected milk basis. FPCM was calculated using the formula **(FPCM (kg/yr) = Production (kg/yr) x [0.1226 x Fat% + 0.0776 x True Protein % + 0.2534]**.

If corrected to FPCM using year 3 data, average yield across 415 farms would be deemed to increase by 1.04%. The maximum individual herd increase was 20.6%, and the greatest decrease was 7.8%. The mean yield per cow using this methodology was 7,792 kg/year. This is comparable to 7,587 litres/year, if the density of milk is assumed to be approximately 1.027 kg/litre; the average non-adjusted yield was 7,735 litres.

In general, if carbon footprint was expressed on a FPCM basis, then for this sample of farms the average carbon footprint would reduce slightly. Correction to a fat and protein basis has potentially greater relevance to high constituent manufacturing milk.

### International Dairy Federation compliant carbon footprint

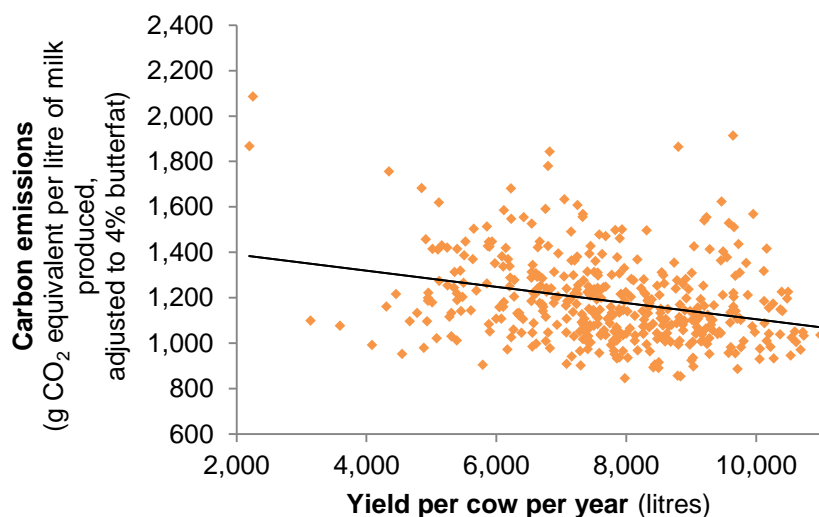
The calculated IDF figure for the full year 3 dataset (415 farms) was 1,252 g CO<sub>2</sub>e/litre of fat and protein corrected milk, presented as a weighted average. The comparable figures in years 1 and 2 were 1,327 g CO<sub>2</sub>e/litre and 1,270 g CO<sub>2</sub>e/litre respectively.



## Relationship of carbon foot print with production parameters

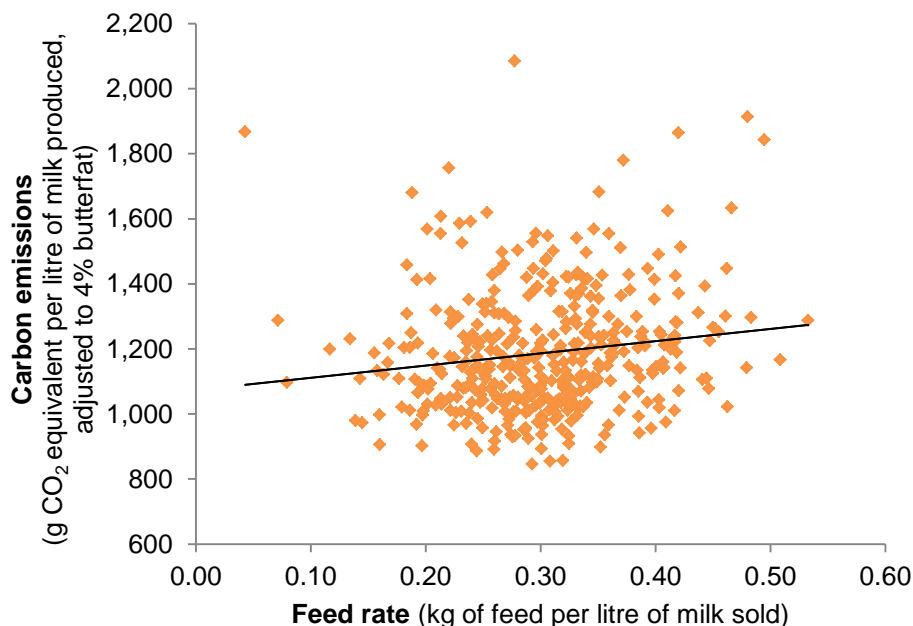
Year 3 data are presented below plotting carbon foot print against a range of production parameters. The graphs are very consistent with outputs from the first two years of the study, and underline the wide range in farm carbon foot print seen in the industry.

### Carbon footprint and milk yield



Higher milk output, for a given level of input, means there is a greater volume of milk over which to spread the carbon cost. However, the large range in carbon foot print observed, irrespective of yield, clearly indicates that yield level is not the only factor affecting carbon foot print.

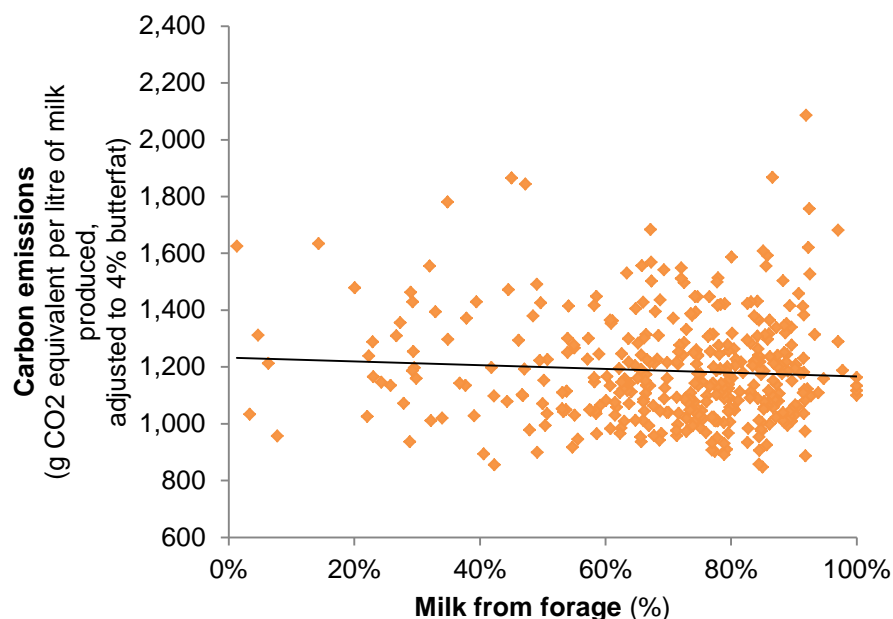
### Carbon footprint and concentrate feed rate



Similarly, there is a wide dispersion of carbon foot print with concentrate feed level (kg/l milk). For the sample as a whole, the average concentrate feed rate was 0.30 kg/l milk sold. In this context, concentrates are defined as dry feeds – dry straights, concentrates, and non-forage home grown feeds. Moist feeds such as wet brewers grains were not classed as concentrate by the

carbon calculator used. While there is a positive association between concentrate feeding levels and carbon foot print it is not a strong one, given that higher concentrate levels are also likely to be associated with higher yields.

## Carbon footprint and milk from forage



Milk from forage was also analysed relative to carbon footprint. This was carried out by calculating milk produced from concentrates, and subtracting this value from total yield on a yield per cow basis. Milk produced from concentrates was calculated using the following formula.

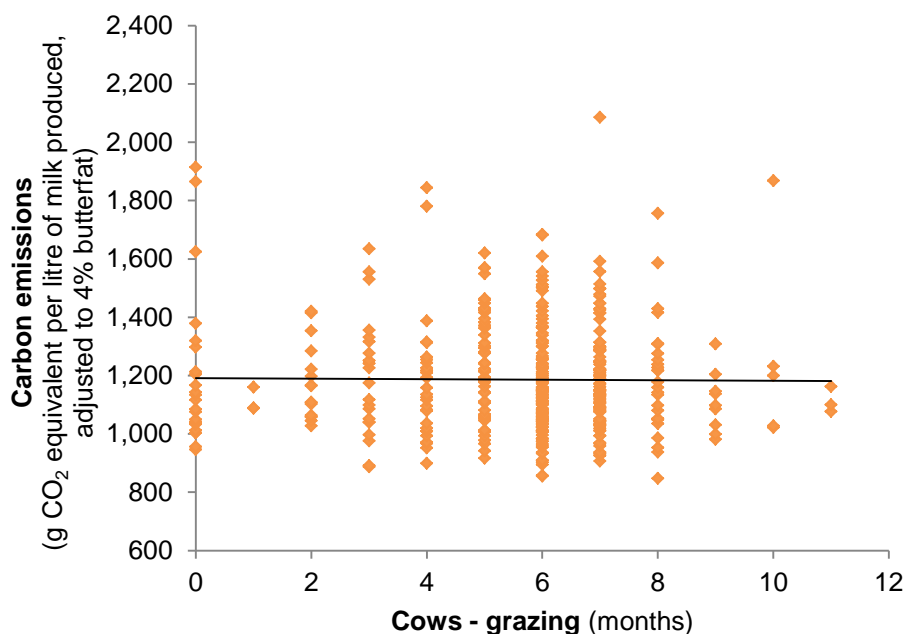
### Milk from concentrates = Production (l) – [(Concentrate use (kg)/0.45)/days]

As a function of total milk produced from concentrates, on average 5,465 litres was produced per cow annually; 71% of the total milk produced. There was no strong correlation between milk from forage and carbon footprint.

The range in milk output from forage varied from 1.3% to 100%. This highlights limitations in estimating milk from forage by reverse calculation and, potentially, major inefficiencies in some feeding regimes. For some “high input systems”, these outlying figures suggest that no milk was produced from forage. Since it is improbable for a cow to produce no milk from forage (where milk produced from concentrates is calculated to be greater than the total yield reported), overfeeding and/or wastage of concentrates is a potential cause.

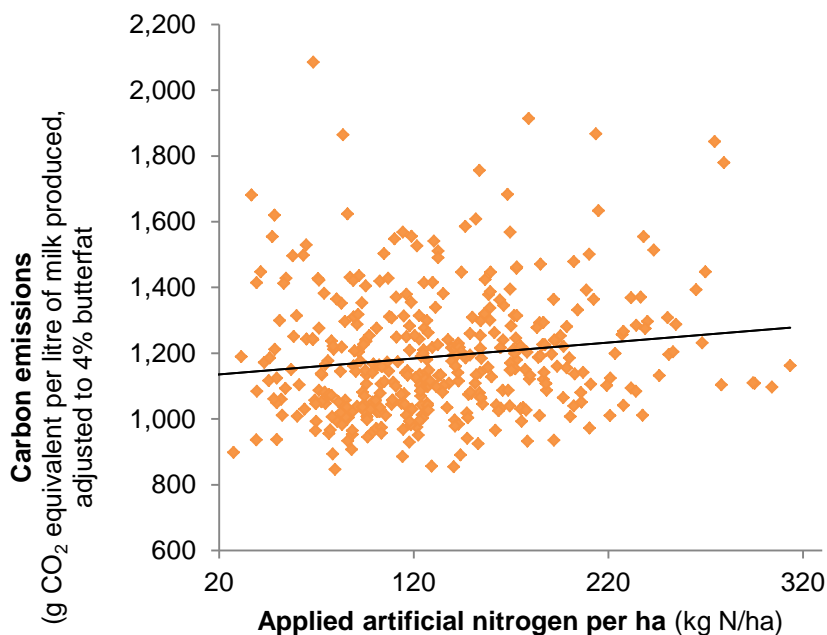
Additionally, concentrate wastage could be occurring because of an imbalanced diet, or underlying health issues.

## Carbon footprint and length of grazing season



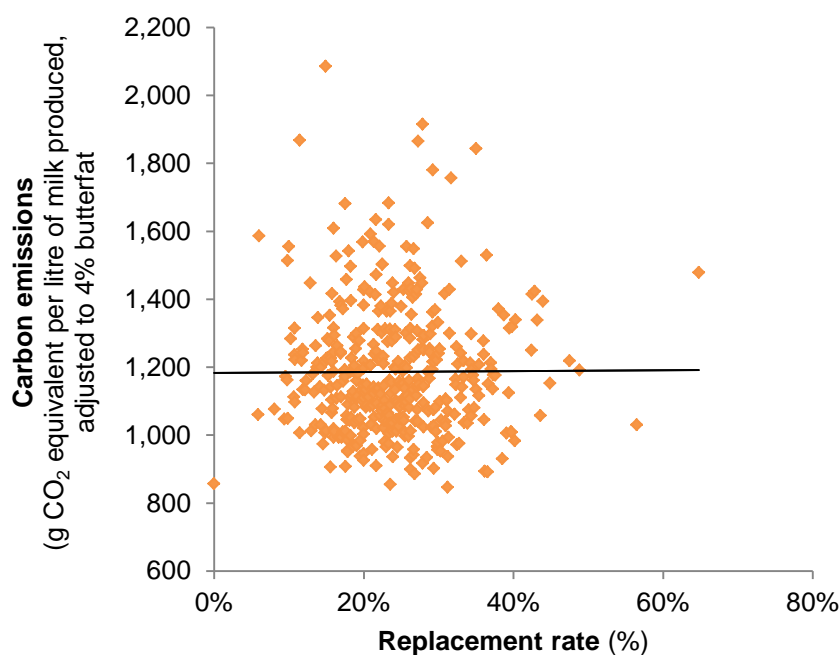
Carbon footprint was also examined as a function of the time lactating cows were grazed. The average time grazing was 5.5 months. No correlation was found between length of grazing season and carbon footprint.

## Carbon footprint and N-fertiliser use



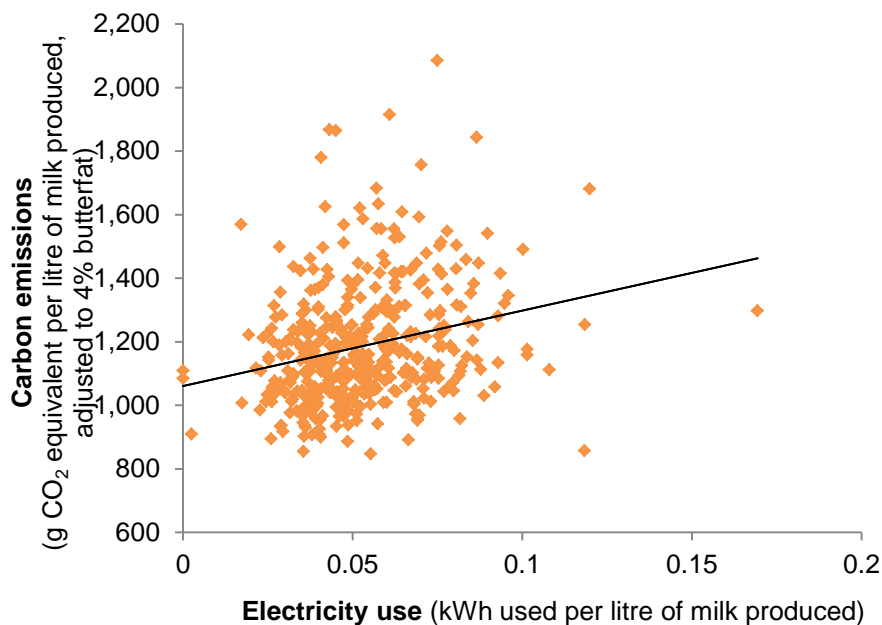
As in earlier years, a wide range of synthetic fertiliser application rates were recorded. Efficient use of fertiliser should result in greater amounts of herbage produced per kg fertiliser applied, and/or increased herbage yield to offset the need for purchased feeds. In addition, making optimum use of slurry and organic manures will reduce the need for artificial fertiliser inputs and associated impacts on GHG emissions.

## Carbon footprint and herd replacement rate



Most participating farms had replacement rates between 10% and 40%. For the sample as a whole, there was a poor association between carbon footprint and replacement rate. Rates are dependent on a variety of factors (including some beyond the farmers control e.g. removal of animals for TB), and can vary significantly from season to season. By replacing less efficient cows, a farm can potentially achieve more efficient production and resource utilisation, in the long run.

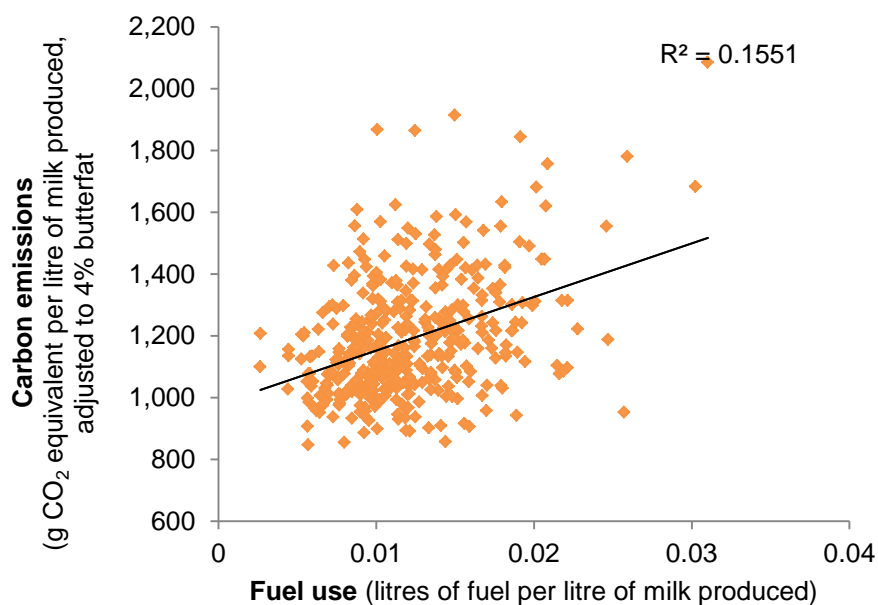
## Carbon footprint and electricity use



Within this analysis, electricity use is limited to the mains supply, and excludes any home produced green energy. Electricity use in Year 3 contributed, on average, only 3% to the overall carbon footprint. Despite this, the correlation with carbon footprint is one of the stronger relationships in the data set. Electricity has a direct and very visible cost associated with it,

making its management more transparent to the farmer. It may be that good energy management is a proxy for good environmental performance generally, including carbon footprint.

## Carbon footprint and fuel use



There is often a perception that fuel use is a large contributor to the carbon footprint of a farm. However, fuel represents only 3% of the average carbon footprint. As with electrical use, increased fuel efficiency is a tangible, cost-saving step that may act as stimulus towards further resource efficiency measures.

## Conclusions

The key objective of this study was to benchmark the carbon foot print of GB milk, using a robust data set and universally accepted methodology. This has now been achieved over three years, drawing from the results of 1,245 farm carbon assessments undertaken since the beginning of the project in 2010.

Fundamental to this objective was to maintain farmer participation in the study year-on-year. The fact that 73% of farmers entering the study completed all three years was particularly pleasing, especially given the challenges faced by the dairy industry during this particular period.

The weighted average foot print (g CO<sub>2</sub>e/l ) recorded for GB milk was 1,293, 1,227 and 1,177, for years 1 to 3 respectively - an overall reduction of 9.0%. This was consistent with a core sample of 305 farms, who completed all three years of the study, and recorded average footprints of 1,287, 1,220, and 1,183 g CO<sub>2</sub>e/litre for years 1 to 3 respectively – equivalent to a reduction of 8.1%.

There was also a high level of consistency in the results obtained calculating carbon foot print according to International Dairy Federation methodology (1,327, 1,270 and 1,252 g CO<sub>2</sub>e/litre of fat and protein corrected milk for years 1 to 3 respectively).

It could be expected that a decrease in emissions would follow from changes in management and other practices, adopted as a result of carbon foot printing. In part, the outcome may also be due to increased milk yield. Average milk yield increased from 7,490 to 7,616 and 7,735 litres per animal, between years 1 and 3 respectively. A similar pattern was seen in the 305 'core' farms completing all three years (7,305, 7,565, and 7,578 l in each year respectively).

There was wide farm to farm variation in carbon footprint, with the best operators producing results around 1000 g CO<sub>2</sub>e/l, or less. There was also strong positive relationship (correlation coefficient = 0.62) between individual farm carbon foot print from year to year, reinforcing the view that individual farm circumstances and level of management applied that are the main drivers of carbon foot print.

Although some trends were observed, and in the direction anticipated, significant correlations between variables proved difficult to determine across the dataset as a whole. Correlations between farm energy use (electricity and fuel) and carbon footprint were the strongest. Those farms that efficiently utilised electricity and fuel were more likely to have a lower carbon footprint. Since electrical use and fuel use each contributed only 3% to carbon footprint, it is unlikely that efficient use of either resource in itself drove carbon reduction. However, it may be that fuel and electricity use is an indicator of overall attitude to efficiency on the farm.

From the results of this work, no one farming system or size of herd, was inherently more carbon efficient than another. This means that improvement is possible across all systems, by focussing on key performance areas of resource use efficiency – milk output, feed efficiency, herd replacement rate, fertiliser and manure use. Different combinations of management can be used to achieve overall efficiency, and there is no 'one-size-fits-all' solution to reducing carbon emissions.

It follows that optimising the use of resources within the farming system chosen and good technical management, will not only result in improved productivity and profitability, but also in lower carbon emissions.

## Acknowledgements

DairyCo and E-CO<sub>2</sub> would like to thank all of the organisations and individuals who have contributed to this study, notably:

- All 415 dairy farmers who participated each year, and in particular the 305 farms who completed three years of the study
- Arla Foods UK
- Arla Milk Link
- Belton Cheese
- Cropwell Bishop Creamery
- First Milk
- Müller Wiseman Dairies
- OMSCo
- A number of independent farms – including suppliers of Ashley Cheese, Barbers Maryland Cheese, Dairy Crest, Freshways, Glanbia, Kraft Foods, Lactalis, R Grahams, The Fresh Milk Company, and Marks & Spencer.

## Glossary

**Atmospheric deposition** – The transfer of substances from the air to the surface of the earth, either in a dry form through gases and particles or a wet form in rain, snow and fog. Within agriculture it should be considered from all sources of additional N-load on soils and from manure storage.

**Carbon Dioxide Equivalents (CO<sub>2</sub>e)** – CO<sub>2</sub>e is a standard unit for measuring carbon footprint and describes for a particular greenhouse gas the quantity of carbon dioxide that would have the same global warming potential, calculations are based on the global warming potential of each greenhouse gas

**Carbon footprint** – The total set of GHG emissions caused directly and indirectly by an individual, organisation, event or product.

**Correlation** – A statistical measurement of the relationship between two variables. Possible correlations range from +1 to –1. A zero correlation indicates that there is no relationship between the variables. A correlation of –1 indicates a perfect negative correlation, meaning that as one variable goes up, the other goes down. A correlation of +1 indicates a perfect positive correlation, meaning that both variables move in the same direction together.

**Distribution** – An order or pattern formed by the tendency of a sufficiently large number of observations to group around a central value. The familiar bell-shaped curve is an example of normal distribution in which the largest number of observations is distributed in the centre, with progressively fewer observations falling evenly on the either side of the centre (average) line. See also frequency distribution, normal distribution, and standard distribution.

**Enteric fermentation** – The process in which microbes resident in the animal's digestive system ferment the feed consumed by the animal. The by-product of this process is methane which is emitted from the animal and results in lost energy.

**Greenhouse Gases (GHG)** – Gaseous constituents of the atmosphere that occur from natural processes and human activities. These gases emit and absorb heat and are said to be contributing to the warming of annual global temperatures. The principal greenhouse gases that enter the atmosphere as a result of human activity are carbon dioxide, methane and nitrous oxide

**Global Warming Potential (GWP)** – A measure of how much a given mass of GHG is estimated to contribute to global warming. It is a relative scale which compares the gas in question to that of the same mass of CO<sub>2</sub> (whose GWP is by convention equal to 1 when considered over a 100 year period).

**Life Cycle GHG Emissions** – Sum of greenhouse gas emissions resulting from all stages of the life cycle of a product and within the specified system boundaries of the product.

**Mean** – The most commonly used form of statistical average. It is calculated by finding the total sum of the data set and dividing this by the amount of data. This gives an indication of the average number of the dataset. The advantage of using the mean is that it minimises the error within the given average. The mean however is not always the best form of average to use, as it can be easily affected by anomalies within the data set.

**Median** – The middle number (in a sorted list of numbers). To obtain the median, place a dataset in value order and find the middle number

**Mode** – The value that occurs most often. If no number is repeated, then there is no mode.

**$r^2$  (r-squared)** – Is the coefficient of determination and is defined as the percent of variation in the values of the dependent variable (y) that can be explained by variations in the value of the independent variable (x).

**Range** – The difference between the largest and smaller number in a dataset.

**Skewness** – The degree to which a statistical distribution is not in balance around the mean (is asymmetrical or lopsided). A perfectly symmetrical distribution has a value of 0. Distributions with extreme values (outliers) above the mean have positive skew, and the distributions with outliers below the mean have negative skew.

**Standard deviation** – Is a measure of the dispersion of a set of data from its mean. The more diverse the spread of data, the higher the deviation from the mean. Standard deviation is calculated as the square root of variance.

**Standard error** – Is the estimated standard deviation or measure of variability in the sampling distribution of a statistic. A low standard error means there is relatively less spread in the sampling distribution. The standard error indicates the likely accuracy of the sample mean as compared with the population mean. The standard error decreases as the sample size increases and approaches the size of the population.

**Sustainable agriculture** – Sustainable agriculture simultaneously increases production and income, adapts to climate change and reduces GHG emissions, while balancing crop, livestock, fisheries and agroforestry systems.

**Variable** – A characteristic, number, or quantity that increases or decreases over time, or takes different values in different situations. There are two basic types which are (1) Independent variable: that can take different values and can cause corresponding changes in other variables, and (2) Dependent variable: that can take different values only in response to an independent variable.

**Weighted mean** – An average in which each quantity to be averaged is assigned a weight. These weightings determine the relative importance of each quantity on the average. Weightings are the equivalent of having that many like items with the same value involved in the average.



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DairyCo  
Agriculture and Horticulture Development Board  
Stoneleigh Park  
Kenilworth  
Warwickshire  
CV8 2TL

T: 024 7669 2051

E: [info@dairyco.ahdb.org.uk](mailto:info@dairyco.ahdb.org.uk)

[www.dairyco.org.uk](http://www.dairyco.org.uk)

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