ON-FARM CARBON STEWARDSHIP: USING CASE-STUDIES TO EXPLORE THE SCOPE FOR REDUCING GREENHOUSE GAS EMISSIONS FROM FARMING

A Study by

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1. INTRODUCTION

1.1 This report

This is a report on one of four studies that have been carried out as part of the project "***The carbon footprint of UK agriculture***"[1]. It accompanies reports on each of the three other studies.

1.2 "The carbon footprint of UK agriculture"

"***The carbon footprint of UK agriculture***" is a project supported by the Frank Arden Memorial Award, with further support from the Nuffield Farming Scholarships Trust (NFST), the Esmé Fairbairn Foundation and eight other strategic partners.

It was originally proposed by members of the Arden Family; following discussion and development with the NFST, it was agreed that the project should comprise the four studies and a dissemination conference, with the following overall aims:

> ***to inform the farming community and stimulate individuals to address the carbon footprint of their business in a positive light, making the subject accessible to the farming community and demonstrating agriculture's potential contribution to tackling climate change***.

The project began in January 2007 and the conference at which its findings were first disseminated took place on April 30th 2008. The four studies took place concurrently between these two dates.

1.3 The study described in this report

The study which is the subject of this report had the following aim:

> ***to investigate, using case-study farms, the scope for adopting on-farm carbon stewardship practices that might contribute to reducing emissions of greenhouse gases from farms.***

The study involved a desk-based estimation of current emissions and sequestration of greenhouse gases on four case-study farms, followed by an examination of the scope for adopting on-farm "carbon stewardship" practices (those that would reduce emissions and/or boost sequestration) and an estimation of the difference these practices would make. More details of how the study was conducted are given in section 2.

1.4 Some explanatory notes

The project "***The carbon footprint of UK agriculture***" is concerned with all the greenhouse gases which link agriculture to global warming; it is not solely concerned with carbon dioxide. In other words, the term "carbon footprint" has been adopted as shorthand for emission and sequestration of all greenhouse gases; this has been done for simplicity and in order to engage interest at a time when the terms "carbon footprint", "low-carbon economy" are in common use elsewhere in the food supply chain and the wider economy.

The same shorthand is adopted in this report. Hence “carbon stewardship” practices are practices which address any of the greenhouse gases (not just carbon dioxide). But for the avoidance of doubt the term “greenhouse gases” is used in the report and refers to carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). The unit of measurement for all these gases, singly or in combination, is tonnes carbon dioxide equivalent (tonnes CO_2e).

2. HOW THE STUDY WAS CARRIED OUT

2.1 Overview

To carry out this study, three "ingredients" were needed:

- Farm businesses willing to be **case-studies**;
- A **method of estimating emissions and sequestration** of greenhouse gases from those businesses;
- **Information on "carbon stewardship" practices** – possible measures those businesses could take to reduce their emissions.

This section gives some background on how and where these ingredients were found and, in section 2.5, how they were used to conduct the study.

2.2 The Case-Studies

Direct approaches were made to farmers and farm advisers known to the author and, using the Nuffield network, a general invitation was extended to Nuffield scholars to indicate if they would be interested in being a case-study. Although the level of response was generally disappointing, this generated a long-list of c. 10 businesses of various types and sizes that were potentially interested in taking part.

Each was asked some initial questions to ascertain the feasibility of being a case-study. Then, taking into account the answers to these questions and the objective agreed with the sponsors (to cover at least three case-studies representing arable, horticultural and intensive livestock enterprises), four case-study businesses were chosen:

Case-study A – an arable business in Lincolnshire;
Case-study B – an arable business in Yorkshire;
Case-study C – a horticultural business in Lincolnshire;
Case-study D – a pig business in Yorkshire.

(For details on each, please see the appropriate sub-section in section 3).

2.3 A method of estimating emissions and sequestration

Thanks to the generosity and cooperation of the Country Land and Business Association (CLA), this study has been conducted using the "CALM" model to estimate emissions and sequestration.

CALM stands for Carbon Accounting for Land Managers. CALM is a business-based calculator showing the balance between annual emissions and sequestration of the key greenhouse gases associated with the activities of land-based businesses.

It has been conceived by the CLA and developed by them with support from Savills, the East of England Development Agency and the Crown Estates.

CALM was being developed during the period of the study and so its use for this study contributed to its testing and piloting. The model has since been made publicly and freely available[2].

The development of CALM marks a significant step forward for the farming and other land-based sectors in acknowledging and beginning to tackle their greenhouse gas emissions. It is, for instance, on a par with DETR[a]'s development of guidelines for greenhouse gas reporting[3] or sector-specific guidance on greenhouse gas reporting[4].

But it is a development that has taken place alongside many others connected with the subject of global warming, at a time when many different and often ill-defined terms have crept into the vernacular.

In a crowded field, it is important to know exactly which beast you are talking about! In reading this report, which relies heavily upon the methodology of CALM, it is important to note:

i. The difference between enterprise-accounting and product-accounting;
ii. That CALM is based on internationally-agreed parameters for estimating emissions and sequestration from different activities, scaled-down for use at individual enterprise level.

i. Enterprise-accounting vs. product-accounting

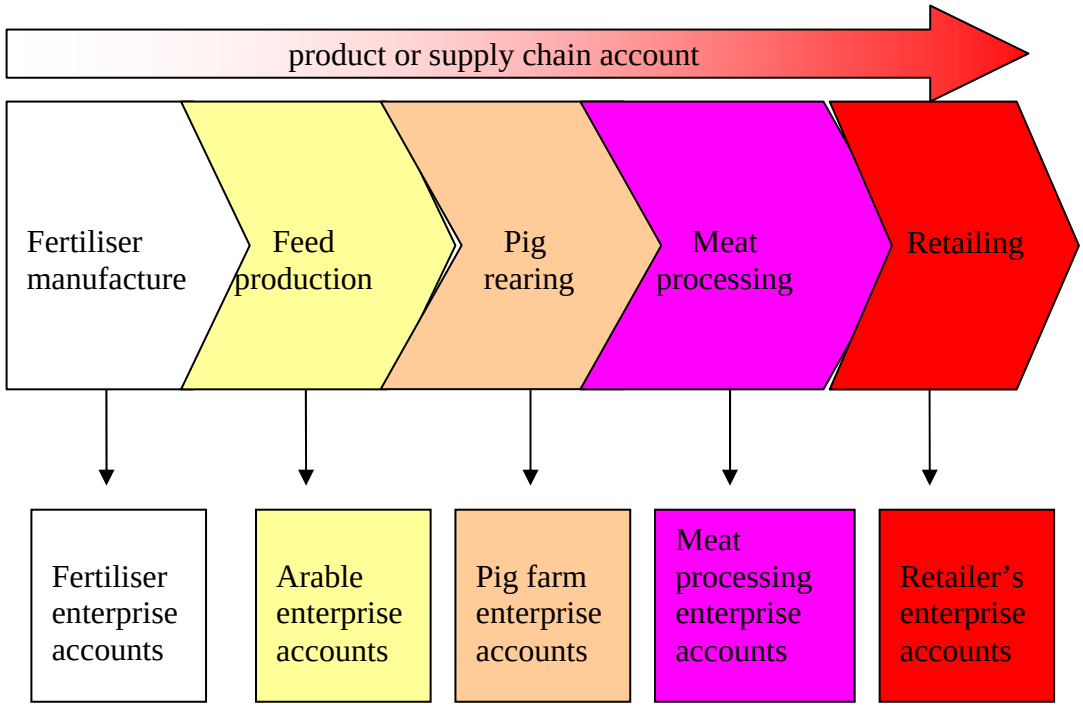
CALM is a method of estimating the annual emissions and annual sequestration of greenhouse gases from a business. It is an example of "enterprise-accounting" - accounting for the emissions and sequestration that are a direct consequence of the activities of the enterprise being considered. An estimate for a farm prepared using CALM is equivalent to an estimate that might be prepared by a company and published in its annual report, perhaps in response to investor interest or in accordance with good practice for corporate social responsibility. (In the language that has grown up around international protocols for greenhouse gas accounting, it corresponds to accounting for the "Scope 1" and "Scope 2" emissions from a business, but excludes the "Scope 3" emissions which are those associated with the production of bought-in materials, with products in use and activities that are out-sourced[5].)

Enterprise-accounting, of which CALM is an example, is different from but related to "product-accounting" (sometimes known as "supply chain accounting"). Accounting for the "carbon" (greenhouse gas) emissions and sequestration of a product means accounting for the greenhouse gases at every stage in its production, including bought-in materials and their transport, and onwards transport to the point at which the product is made available to the consumer.

The difference and the interconnections between these two concepts, in the case of producing meat products, are illustrated (very simply) in Inset 1.

[a] Department for the Environment, Transport and the Regions, now Department for Environment, Food and Rural Affairs (Defra).

Inset 1: Enterprise vs. product or supply chain accounting in the production of meat (adapted from Carbon Trust, 2006)



Clearly, one way to estimate the so-called carbon footprint of a product is for each party in the supply chain to do their enterprise accounting and for these accounts to be added together and normalised (e.g. per unit of product).

(There are other methods, using for instance mass-balance calculations).

In practice, this is a complicated task, not helped by the fact that there is no agreed methodology for it. But the starting point is the preparation of enterprise accounts by each party in the supply chain. Hence estimating greenhouse gas emissions and sequestration using a tool such as CALM is not just a useful tool for managing emissions; it is a first step for any farm business that wishes or is required (as a condition of business) to assist retailers develop carbon footprints or carbon labels for specific food products.

ii. Internationally-agreed parameters, scaled down

The negotiations that led to the 1997 Kyoto Protocol and subsequent developments have stimulated a great deal of scientific research into the sources and sinks of greenhouse gases. CALM is based on the internationally agreed parameters that underpinned the Kyoto protocol or, where possible, more sophisticated parameters developed and agreed since then as a result of Kyoto commitments. It then scales these parameters down for use at individual farm level.

These parameters represent best-available scientific consensus at international level. There are – to the knowledge of either CALM's creators or the author – no other parameters that could have been used to create a model of equivalent usefulness, workability and availability to farmers - now, in 2008!

But, from an individual farm perspective, some of these parameters can seem somewhat broad brush – especially where they concern N_2O and CH_4 production which are of course of greatest relevance to farming. For example:

- emissions of CO_2 from the use of electricity are estimated using a standard figure which represents the use of fossil fuel by the UK electricity supply industry – the so-called national energy mix;
- emissions of N_2O attributable to the return of crop residues to the soil are estimated using a standard figure to estimate crop residue from yield and another to estimate N_2O emissions from crop residue.

This means that CALM does not and cannot pick up possible differences between farms that might result from, for instance, differences in soil type, microclimate, or management. It is not, therefore a tool for benchmarking one farm against another and insofar as it can be used to compare one year with another on a single farm, this is possible only in the terms in which the parameters are defined.

Given the uncertainty surrounding the routes by which CH_4 and N_2O are emitted or sequestered in farming and the factors influencing the flux between these routes, the use of such broad parameters is justifiable. To put it the other way around, any attempt at further precision would have been misleading - and a waste of money! But it does impose certain limits on the interpretation of the findings presented in section 3 and discussed in section 4; it is important they are acknowledged.

2.4 Information on "carbon stewardship" practices

The environmental, farming, scientific and policy literature is full of information on how greenhouse gas emissions can be reduced and sequestration promoted. Some is speculative, some lacks credibility and some has been developed in isolation from other considerations such as viability, or meeting other environmental objectives (e.g. water quality). Because of the uncertainties surrounding the subject, information which quantifies likely effects of different practices and which can be applied to a range of farm situations is in short supply.

For this study, initial information on possible practices was obtained from sources including the Environment Agency[6], the NFU/CLA/AIC[7], Farming Futures[8], Defra[9], the Carbon Trust[10, 11], and its predecessor[12].A list of stewardship practices that might be adopted on farms, together with an estimate of their likely effect was compiled. This list is presented in Inset 2.

2.5 Putting it all together

The study began in summer 2007 and the first phase included a review of the literature, the identification of CALM as a highly suitable model and discussions with the CLA. The search for case-study businesses took place in the autumn of 2007. Each of the selected businesses was visited in the period December 2007 – February 2008 and, using the Stage 2 pilot version of CALM plus information from the case-study farm records, an initial estimate of that business's emissions and sequestration over a single year was generated. In some case, this took several iterations – either to allow for developments in the CALM methodology or to acquire and revise the data provided.

The exact choice of year depended on the case-study in question (see the discussion of each case-study in section 3); broadly, the aim was to use the most recent 12-month period for which data was available and which corresponded with the usual "cropping year" for that particular business.

For each case-study, the current practices adopted by the business and the range of possible carbon stewardship practices (see 2.4 above) were then compared and discussed. Practices already adopted were identified as such. Then, two possible carbon stewardship scenarios for each case-study business were devised.

- **Carbon Stewardship Level I**: the business adopts those practices on the currently available list that are not already adopted, that are relevant to the business and that – in the opinion of the business - are practicable.

- **Carbon Stewardship Level II**: the business adopts practices on the currently available list that are – in the opinion of the business – possible but "radical", (and other practices are amended accordingly).

What is "practicable" and what is "radical"? Necessarily – and quite properly given the aims of the study – this had to be a subjective judgement, made from the perspective of the business concerned. In broad terms, the guiding principles were as follows:

- Level I practices should be those that the business saw as practicable, and could envisage being adopted within the next 1 or 2 cropping years, using the available resources of the farm while maintaining broadly similar farm structure, income and management.

- Level II practices were those that could be *envisaged*, but would entail a markedly different approach to the business with, for instance, a big change in man-hours or management, and/or a significant injection of capital.

It is important to note that, in the context of this study, Level I and Level II are relative terms, from the point of view of the business concerned, but are not indicators of the relative achievements of the case-studies in this report. It is also important to note that the case-studies were encouraged to devise scenarios *as if* they were free to operate in isolation from such considerations as supply, or knock-on effects outside the business. This was essential for practical and illustrative purposes but does impose certain limitations on applying the findings of this study to the national picture.

Having identified the Level I and Level II Carbon Stewardship scenarios for each case-study, new estimates of emissions and sequestration under each scenario were prepared and compared with the initial estimate already prepared. CALM does not – at present – allow for the effects of adopting all the different mitigation practices noted in Inset 2 to be tested quantitatively[b]. So, the estimates for the two scenarios were prepared using a combination of CALM and manual calculations.

[b] It is possible to obtain some information on the effects of different scenarios by adjusting the input numbers but this does not cover all the practices available. The CLA plan that this facility will be included in the next stage of its development.

Inset 2: Carbon Stewardship practices currently available to farmers and their estimated effects

Practice	Estimated effect	Source
Improve energy management on farm		
Improve heating and ventilation management of buildings (e.g. with insulation, controls, and regular maintenance)	Up to 15% of heating costs may be saved by combination of measures	Carbon Trust[13]
Improve lighting management (e.g. with occupancy sensors, low-energy lights and better use of daylight)	Up to 15% of lighting costs may be saved by combination of measures	Carbon Trust[14]
Improve refrigeration management (e.g. with insulation, regular maintenance and correct control of levels)	Not specifically estimated	Carbon Trust[15]
Improve vehicle fuel consumption (e.g. by using appropriate machinery for the job, checking tyres, lubricants and steering, and adopting fuel-saving driving style)	Poor driving may add 20% to fuel consumption	Carbon Trust[16]
Monitor energy use and benchmark year-on-year	Up to 5% of energy costs may be saved by monitoring and checking	Carbon Trust[17]
Make more use of renewable energy		
Use biodiesel (diesel with proportion of diesel in it) in place of conventional diesel	Proportional to use	Biodiesel suppliers
Use biomass for heating	Proportional to the replacement of heating fuel	Various
Obtain electricity from a renewable supplier	Proportional to percentage use	Various
Do not exceed crop N requirements Use a recognised fertiliser recommendation system (e.g. RB209 or PLANET and other supplementary guidance (e.g. precision farming, canopy management techniques) to plan fertiliser applications to all crops. Do not exceed optimum (economic) recommended rates. Time fertiliser applications to minimise the risk of loss of N (e.g. avoid autumn N applications and early spring timings to drained clay soils). Take full account of manure inputs when planning mineral fertilizer applications. Ensure accurate use of mineral fertilisers by proper maintenance, setting and calibration of spreading machinery and the use of good quality fertilisers.	5% reduction in N_2O emissions	Defra[18]

Practice	Estimated effect	Source
Be Fertiliser Adviser Certification and Training Scheme (FACTS) qualified or use a professional FACTS adviser.		
Make full allowance of manure N supply Use a recognised fertiliser recommendation system (e.g. RB209, PLANET, MANNER and other supplementary guidance) and reduce mineral fertiliser N inputs accordingly. Use manure analysis to gain a better understanding of nutrient applications and supply. Keep records of mineral fertiliser and organic manure inputs to individual fields. Be Fertiliser Adviser Certification and Training Scheme (FACTS) qualified or use a professional FACTS adviser.	5% reduction in N_2O emissions	Defra[19]
Spread manure at appropriate times/conditions Do not apply slurry or poultry manure to fields at times when there is little crop requirement, or when there is no crop to utilise the added N.	50% reduction in N_2O emissions, plus further reductions in indirect emissions	Defra[20]
Increase livestock nutrient use efficiency Improve the diets and feeding regimes of livestock to decrease wastage of feed nutrients (particularly protein and energy-yielding compounds) for productive purposes: Avoid diets that contain N in excess of the dietary requirement of the animal. Balance diets for energy and protein to increase the efficiency of N utilisation by the animal. Target specific livestock nutrient requirements for correct genetic potential (i.e. breed), age, sex and production stage. Adjust management regimes to allow more efficient production (e.g. 3x daily milking).	6% reduction in N2O emissions	Defra[21]

Practice	Estimated effect	Source
Make use of improved genetic resources Use of plant and animal genetic resources to improve lifetime efficiency of livestock systems: Increase efficiency of individual animals. Use of improved animal genetics for longevity (including calving ease for dairy cows), fertility, and other non-productive traits. Use of new forage plant varieties for improved nutritional characteristics (e.g. improved amino acid profile, reduced rumen protein degradation, improved fibre digestibility) under grazing and conservation conditions.	Reductions in CH_4 emissions in range 3% to 25% have been cited	Defra[22]
Make use of anaerobic digestion technology for farm manures and slurries Use anaerobic digestion (AD) to treat farm manures and generate CH4 for energy production.	Reductions in CH_4 emissions of up to 90% may be possible	Defra[23]
Change land use - to establish permanent grasslands/woodlands Change the land use from cultivated land to permanent cropping which is either ungrazed or pasture with a low stocking rate and zero or low fertiliser inputs.	Reductions in N_2O emissions proportional to land taken out of arable plus carbon sequestration in the order of 1.9-7.0 t CO_2e /ha/year in initial period plus further reductions in indirect emissions	Defra[24]
Change land use - to grow biomass crops Grow perennial biomass crops (e.g. willow, poplar, *Miscanthus sp.*) to displace fossil fuel use, either through direct combustion or through biofuel generation	Reductions in N_2O emissions proportional to land taken out of arable plus carbon sequestration in the order of 1.9-7.0 t CO_2e /ha/year	Defra[25]

3. FINDINGS

3.1 Case-study A

3.1.1 Description

Case-study A is a c. 400 ha arable business in Lincolnshire. Current emissions and sequestration were estimated for the period 1st September 2006 – 31st August 2007. The main arable crop was winter wheat, plus some oilseed rape, borage and sugar beet. The business also grows *Miscanthus sp*. (60has) and a further c. 14has of short-rotation coppice willow. There are some other small areas of farm woodland and permanent grass was established c. 5 years ago under an arable reversion scheme. Imported wood waste is used to improve soil structure.

3.1.2 Emissions and sequestration under current practice

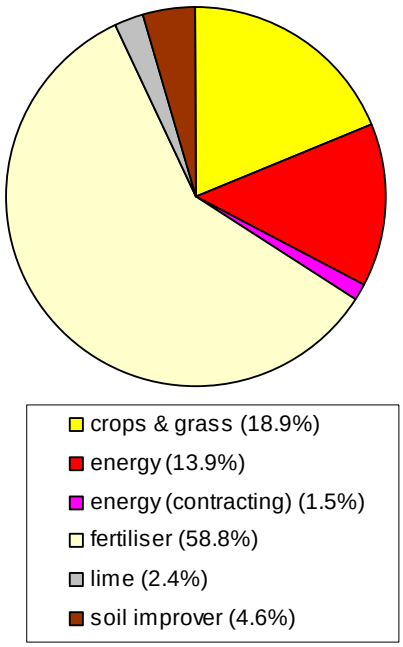
Under current practice, in '06-'07, it was estimated that this business:

- Emitted c. 747 tonnes CO_2e
- Sequestered c. 82 tonnes CO_2e
- And therefore had a carbon balance of c. 665 tonnes CO_2e emitted.

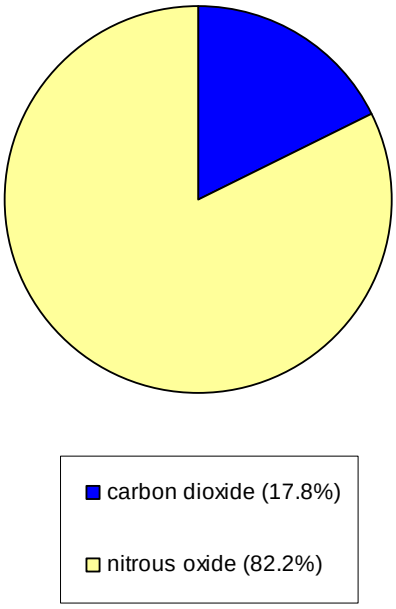
Emissions by source are shown in Inset 3 and by type of greenhouse gas in Inset 4. As expected, the main source is nitrogen fertiliser followed by crops and energy use; nitrous oxide is the main greenhouse gas emitted.

As explained in section 2, these estimates refer to the business; they do not take account of, for instance, "embodied carbon" (emissions from the production of goods or materials subsequently bought-in) or emissions from off-farm transport. Nor do they take account of the fact that, in this particular case-study, the biomass produced is supplied to local electricity-generating stations where it substitutes for fossil fuels. The CO_2 saving which is created by this means is currently in the region of 700 tonnes CO_2e p.a. with the potential to increase to more than 1000 tonnes depending on the development of the yield of the *Miscanthus sp*.

Inset 3: Case-study A
Emissions by source
CO_2 equivalent



Inset 4: Case-study A
Emissions by type
CO_2 equivalent



3.1.3 Carbon Stewardship scenarios

Case-study A already adopts many of the practices that can reduce emissions of greenhouse gases and thus there are only limited options available to improve carbon stewardship. The business identified energy management, and greater use of biomass and of biodiesel as its Level I options; it was not possible to identify any additional practices – however radical – that might take place and thus a Level II stewardship scenario was not developed.

Inset 5: Carbon stewardship scenarios for Case-study A

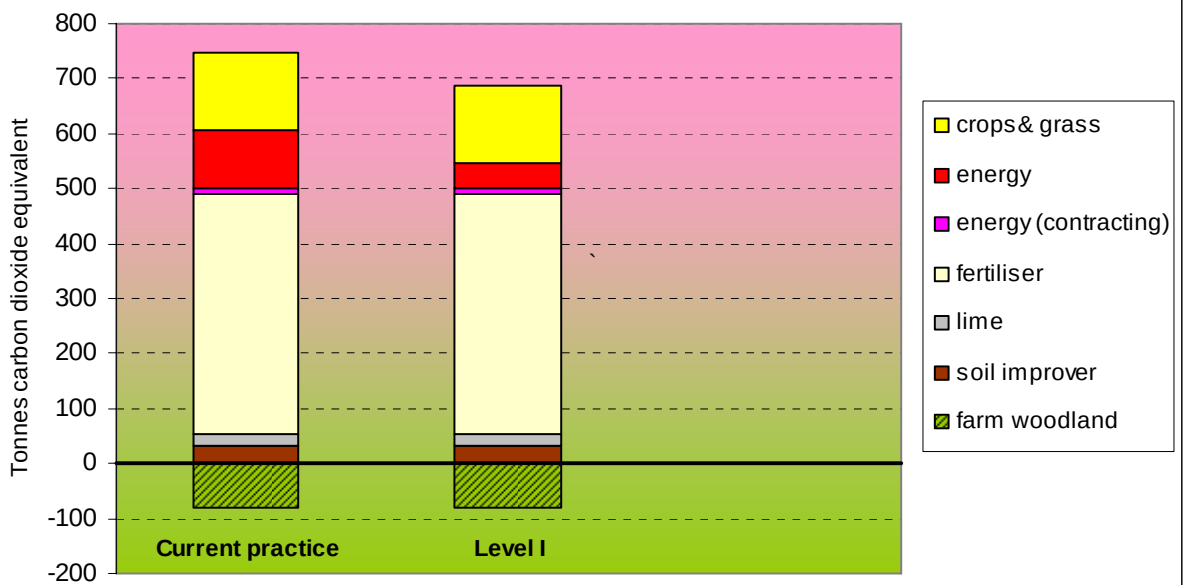
Current practice	Carbon Stewardship Level I	Carbon Stewardship Level II
Crop N requirements are not exceeded (RB209 and FACTS advice are used; applications are appropriately timed); biomass crops are grown; there are woodlands on the farm and some arable reversion schemes have taken place; 5% biodiesel is used.	Energy management: there is scope to manage vehicle fuel and electricity consumption more efficiently. Biomass can be used for heating and the percentage of biodiesel can be increased.	no further practices identified

Under the Carbon Stewardship Level I scenario, it was estimated that this business:

- Would emit c. 689 tonnes CO_2e (8% less than under current practice);
- Would sequester c. 82 tonnes CO_2e (no change);
- And therefore have a new carbon balance of c. 607 tonnes CO_2e.

However, the business would no longer be able to supply as much biomass to local power generators and thus the existing benefit of this (see 3.1.2) would be reduced.

Inset 6: Case-study A: Carbon balance under current practice and Carbon Stewardship Level I



3.2 Case-study B

3.2.1 Description

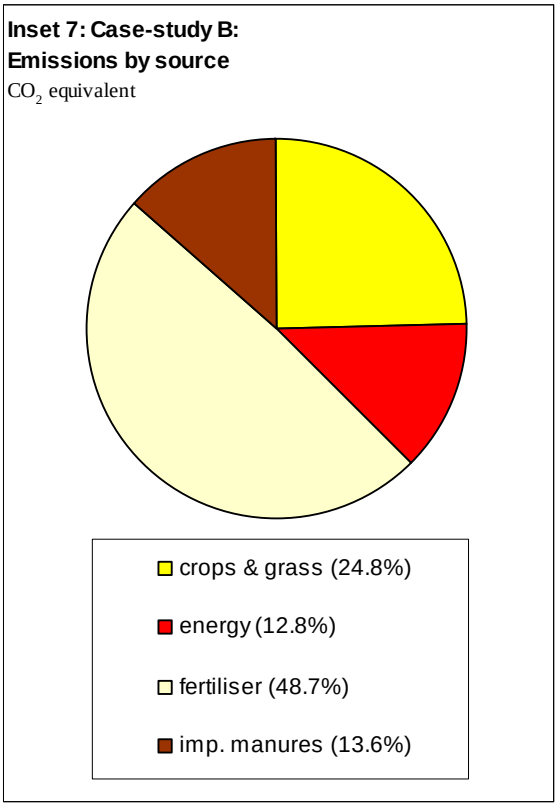
Case-study B is a c. 505ha arable business in Yorkshire. Current emissions and sequestration were estimated for the period 1st October 2006 – 30th September 2007. The main arable crops were winter wheat and oilseed rape; some field beans were also grown. The farm takes liquid manures and solid manures (FYM) from a neighbouring pig business; there is a small area of farm woodland.

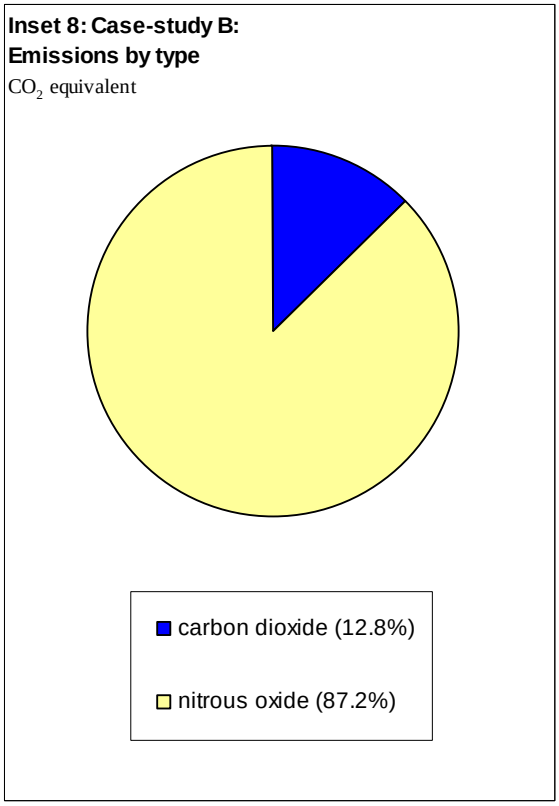
3.2.2 Emissions and sequestration under current practice

Under current practice it was estimated that in '06-'07 this business:

- Emitted c. 1305 tonnes CO_2e
- Sequestered c. 11 tonnes CO_2e
- And therefore had a carbon balance of c. 1294 tonnes CO_2e emitted.

Emissions by source are shown in Inset 7 and by greenhouse gas type in Inset 8. As in Case-study A, the main source is nitrogen fertiliser followed by crops; a significant contribution from the imported manures is evident, on a par with the contribution from direct energy use. The contribution from fertilizer use, crops and imported manures is reflected in the contribution (87%) made by nitrous oxide to the overall mix of greenhouse gases emitted. The sequestration is largely attributable to the Entry Level Stewardship (ELS) strips that were established in the 2006-7 year; it would not therefore be expected to occur in subsequent years.





3.2.3 Carbon stewardship scenarios

For its Carbon Stewardship Level I scenario, this business identified scope to improve vehicle fuel consumption by c. 5% and to obtain its electricity supply from a supplier providing 20% renewable electricity. The other practices (see Inset 2) were already current practice or not applicable.

At Carbon Stewardship Level II, the option of interest was to grow *Miscanthus sp.* on the least productive arable land, amounting to c. 10% of the farm. The scenario assumes that the resulting biomass crop is used to replace fossil fuel currently used for heating and to supply local power generators.

Inset 9: Carbon stewardship scenarios for Case-study B

Current practice	Carbon Stewardship Level I	Carbon Stewardship Level II
Energy consumption in crop drying is minimised to the extent possible. Crop N requirements are not exceeded (RB209 and FACTS advice are used), the nutrient content of slurries and FYM used on the farm are accounted for and applications are appropriately timed. There are ELS strips on the farm, set-aside is remaining permanently out of production; areas of woodland have been established in the last 20 years.	Energy management; there is some scope to reduce vehicle fuel consumption. Use more renewable energy: business could switch to an electricity supplier whose supply is 20% from renewable sources	Grow biomass crops: the business could establish *Miscanthus sp*. on some previously arable land.

Under the Carbon Stewardship Level I scenario, it was estimated that this business:

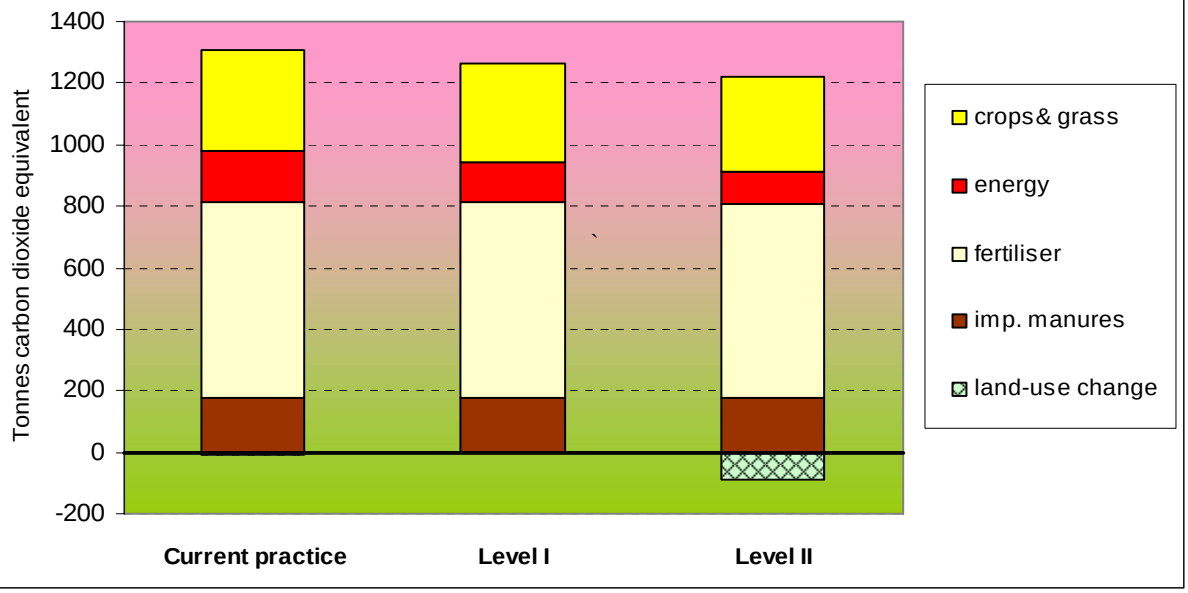
- Would emit c. 1267 tonnes CO_2e (a 3% reduction compared to current practice);
- Would sequester no CO_2;
- And would therefore have a new carbon balance of c. 1267 tonnes CO_2e emitted, i.e. a slight improvement on current practice (especially given the one-off sequestration effect of the ELS strips under current practice).

Under the Level II scenario, the business:

- Would emit c. 1218 tonnes CO_2e (a 7% reduction compared to current practice);
- Would sequester c. 88 tonnes CO_2e;
- And would therefore have a new carbon balance of c. 1130 tonnes CO_2e emitted, i.e. a further improvement on current practice.

The sequestration, which is the effect of establishing the *Miscanthus sp.,* would not reoccur year-on-year. However, there would an ongoing benefit of fossil fuel substitution, not included in the above figures, if the business were to supply the biomass surplus to its own heating requirements to local power generators. (See section 3.1.2.)

Inset 10: Case-study B: Carbon balance under current practice and Carbon Stewardship Levels I and II



3.3 Case-study C

3.3.1 Description

Case-study C is a c. 82 ha horticultural business in Lincolnshire. Current emissions and sequestration were estimated for the 2007 calendar year when the business produced potatoes, daffodils (cut flowers and bulbs), *Delphinium sp* and peonies. During 2007, the business also created nearly 6 has of permanent grassland on previously arable land (through a mix of arable reversion and (ELS) schemes).

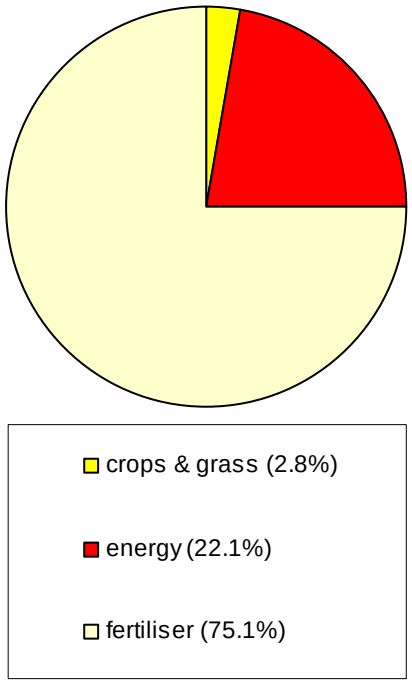
3.3.2 Emissions and sequestration under current practice

It was estimated that in 2007 this business:

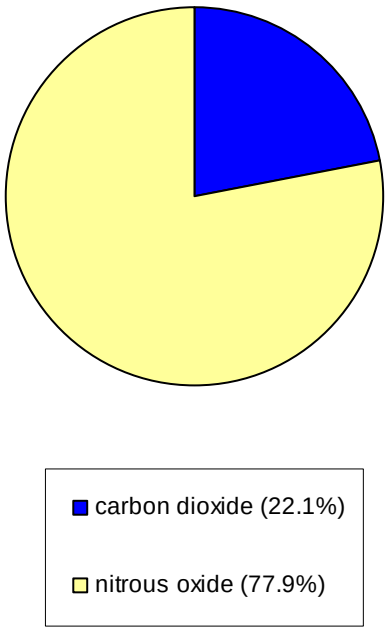
- Emitted c. 607 tonnes CO_2e
- Sequestered c. 17 tonnes CO_2e
- And therefore had a carbon balance of c. 590 tonnes CO_2e emitted.

Emissions by source are shown in Inset 11. As expected, the main source is nitrogen fertiliser and nitrous oxide accounts for nearly 80% of emissions.

Inset 11: Case-study C: Emissions by source
CO_2 equivalent



Inset 12: Case-study C: Emissions by type
CO_2 equivalent



3.3.3 Carbon Stewardship scenarios

The carbon stewardship options that might be adopted by this business under Level I were judged to be those that involved improved management of fuels and changes in fertilizer usage to accord with the horticultural aspects of RB209 and other guidance. It was also judged feasible for the business to switch electricity supplier, to obtain a supply that was 20% renewable, and to use a 20% biodiesel blend.

At Carbon Stewardship Level II, the options of interest to the business were growing biomass and using a “biodigester” (anaerobic digestion plant) to make the business more self-sufficient in energy. It was envisaged that the biodigester would be supplied with potatoes failing to meet customer quality specifications and aboveground, non-crop plant material. Because the business could not on its own produce enough energy-rich plant material, the scenario assumes that the business joins a local consortium operating a small-scale biodigester taking a mix of material from the area, that the business takes back the digestate and receives a supply of electricity (either directly or indirectly) sufficient to meet the business’s remaining needs.

Inset 13: Carbon stewardship scenarios for Case-study C

Current practice	Carbon Stewardship Level I	Carbon Stewardship Level II
Arable land has been converted to permanent grassland under ELS.	Energy management: managing vehicle fuel and electricity consumption more efficiently, improving the efficiency of LPG use for drying and disease control in daffodil bulbs, obtaining a 20% renewable electricity supply and using a 20% biodiesel blend. Fertilizer management: adopting RB209 (or equivalent), improved fertilizer application techniques and use of FACTS advice.	Level I practices plus: Anaerobic digestion of waste plant material. Growing biomass crops on land not used for cut flowers.

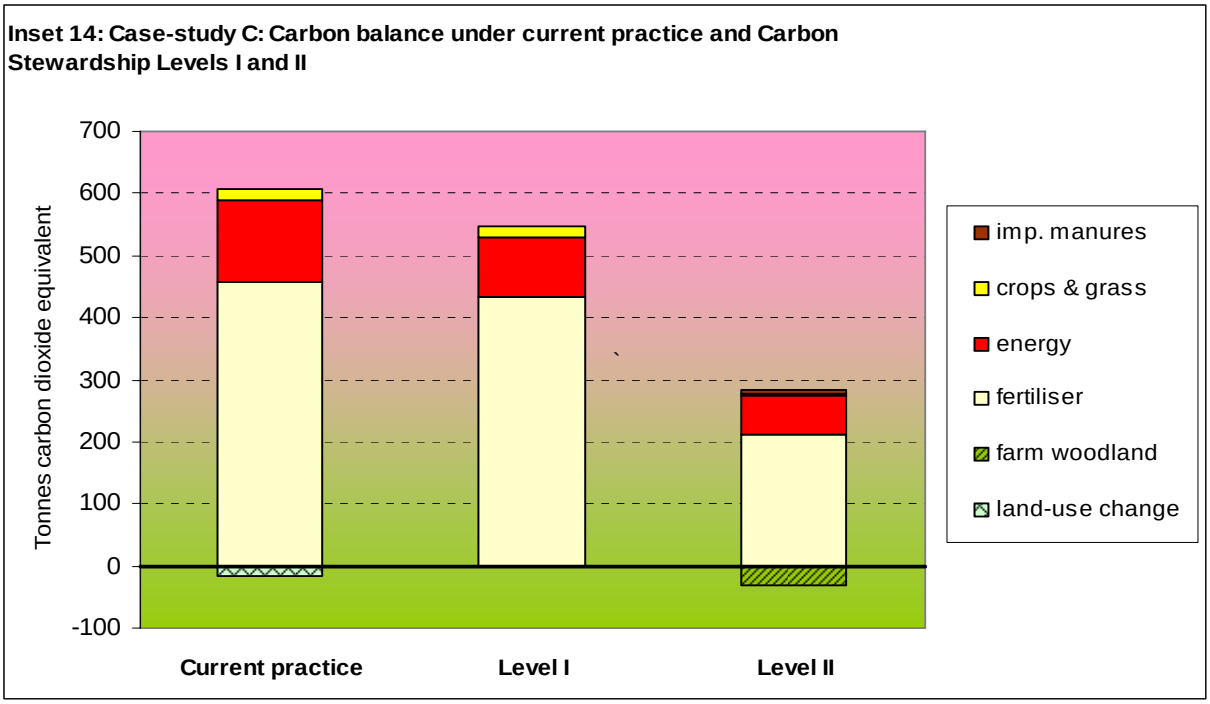
The Carbon Stewardship Level I scenario gave rise to the following:

- Emissions of c. 546 tonnes CO_2e, (10 % lower than under current practice);
- No further sequestration;
- And hence a new carbon balance of c. 546 tonnes CO_2e emitted.

The Level II scenario changed the carbon balance of the business as follows:

- Emissions were c. 284 tonnes CO_2e, (more than 50% lower than current practice);
- Sequestration was c. 31 tonnes CO_2e, (nearly double that under current practice);
- And the new carbon balance was c. 253 tonnes CO_2e emitted.

Inset 14: Case-study C: Carbon balance under current practice and Carbon Stewardship Levels I and II



3.4 Case-study D

3.4.1 Description

Case-study D is a pig-breeding and rearing business in Yorkshire with c. 450 breeding sows. The business has no arable land of its own but disposes of both liquid manures and FYM by arrangement with a neighbouring arable operation. Current emissions and sequestration were estimated for the period 1st October 2006 – 30th September 2007.

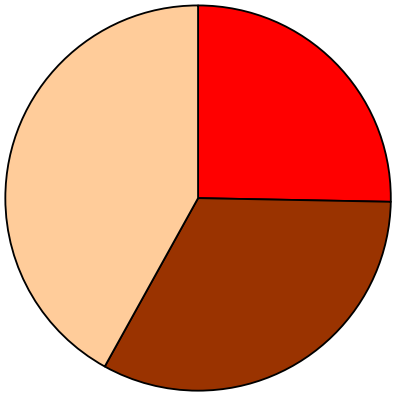
3.4.2 Emissions and sequestration under current practice

Under current practice it was estimated that in '06-'07 this business:

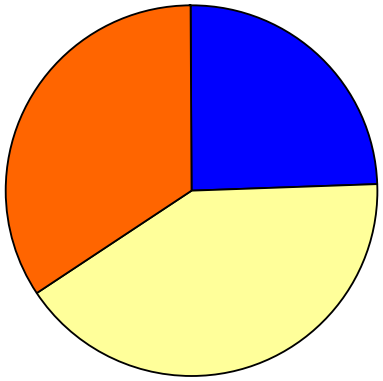
- Emitted c. 363 tonnes CO_2e from the business directly;
- "Exported" emissions of c. 177 tonnes CO_2e, as a result of the off-farm disposal arrangements;
- Sequestered no greenhouse gases;
- And therefore had a carbon balance of c. 540 tonnes CO_2e emitted.

Emissions by source are shown in Inset 15 and by greenhouse gas type in Inset 16.

Inset 15: Case-study D: Emissions by source
CO_2 equivalent



Inset 16: Case-study D: Emissions by type
CO_2 equivalent



3.4.3 Carbon Stewardship Scenarios

This business identified only one practice that it could adopt for its Carbon Stewardship Level I scenario; to switch to a supplier of electricity that would provide 20% of the supply from renewable sources. There was no scope for other practices because energy management has recently been subject to a complete overhaul and improvement, practices to mitigate the emissions of N_2O are already adopted and there is an ongoing programme of breeding stock replacement which ensures nutrient use efficiency is maximised.

For the Carbon Stewardship Level II scenario, the business identified anaerobic digestion (AD) as an option but recognised that it was not a sufficiently large operation to have its own AD plant. The scenario therefore assumes that the business enters into a joint venture with neighbouring livestock businesses, to install and operate an AD plant located on the premises of one of the joint venture partners and fuelled with slurry and other materials. It assumes that the resulting reduction in CH_4 emissions from the business is 60% (i.e. less than the maximum possible reduction of 90% cited in the literature (see Inset 2)) and that spreading digestate from the AD plant on the land has no net effect on emissions of N_2O compared with the spreading of slurry (i.e. the possible stimulation caused by the digestate being richer in nitrogen than slurry is counter-balanced by the lower carbon content)[26]. The scenario also assumes that the business's share in the electricity generated by the AD plant is only sufficient either, to supply pumps necessary to transport the slurry to the AD plant (the business's preferred option) or, to offset the additional emissions resulting from transporting slurry in vehicles. These are probably conservative assumptions.

Inset 17: Carbon stewardship scenarios for Case-study D

Current practice	Carbon Stewardship Level I	Carbon Stewardship Level II
Heating, ventilation and lighting management is given close attention (and was recently overhauled).Breeding stock are continually replaced, to ensure best available nutrient use efficiency. Manure and slurry disposal (on adjoining arable farm) takes place only at appropriate times and when there is a crop requirement.	Use more renewable energy: switch to an electricity supplier whose supply is 20% from renewable sources.	Use anaerobic digestion to treat and generate electricity from manure and slurry.

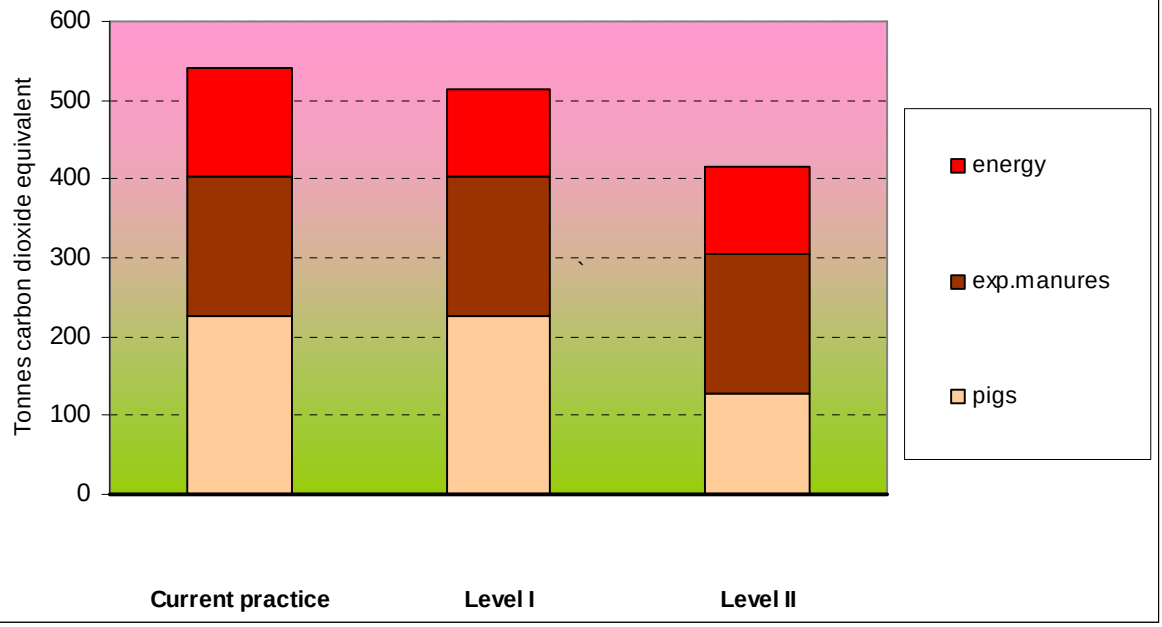
Under the Carbon Stewardship Level I scenario, it was estimated that this business:

- Would emit c. 336 tonnes CO_2e directly, (a 7% reduction compared to current practice);
- Would continue to "export" emissions of c. 177 tonnes CO_2e;
- Would still not sequester any greenhouse gases;
- And would have a new carbon balance of c. 513 tonnes CO_2e emitted.

Under the Level II scenario, the business:

- Would emit c. 238 tonnes CO_2e directly (a 34% reduction compared to current practice);
- Would continue to "export" emissions of c. 177 tonnes CO_2e, through the spreading of AD digestate;
- Would still not sequester any greenhouse gases;
- And would have a new carbon balance of c. 415 tonnes CO_2e emitted.

Inset 18: Case-study D: Carbon balance under current practice and Carbon Stewardship Levels I and II



4. DISCUSSION

4.1 Emissions and sequestration under current practice

4.1.1. The results from each of the four case-studies illustrate at farm business level what is already known about UK farming's contribution to emissions of greenhouse gases, namely:

- The major sources of greenhouse gas emissions are fertiliser usage and arable cropping (producing nitrous oxide) and livestock husbandry (producing methane);
- Energy use is responsible for a small percentage of total greenhouse gas emissions; it accounted for between 5 and 25% in the four case-studies;
- Farm woodlands, and land use changes that convert arable land to permanent cover (grass or woodland), where they occur, make a small contribution to carbon sequestration; one case-study demonstrated no sequestration and on the other three, sequestration was equivalent to between 0.5 and 11% of emissions.

4.1.2. In the two arable case-studies and the horticultural case-study, emissions attributable to fertilizer use accounted for between 48 and 75 % of total emissions; arable and horticultural crops accounted for between 3 and 24%.

4.1.3. In the livestock case-study, pig breeding and rearing accounted for 42% of emissions and the use of manures (on an adjoining farm) for 33%.

4.2 The scope for adopting Carbon Stewardship Level I

4.2.1 The scope for improvement under the Carbon Stewardship Level I scenarios ranges from 3 to 10%. In other words, in all the case-studies, carbon stewardship can be improved, over the next one or two years, simply by adopting practices judged to be practicable and within the available resources of the farm.

4.2.2. Although reductions of this scale could be seen as somewhat insignificant, it is worth noting that they are not out of line with reductions targeted and achieved by other sectors of industry. In the late 1990s and early 2000s, several leading UK businesses set targets to reduce their emissions of greenhouse gases that matched the UK's target under the Kyoto protocol; hence many set themselves the target to reduce emissions to 12.5% lower than their level in 1990, by 2010. We are now nearing the end of this commitment period and Inset 19 gives some examples of reductions that have been achieved to date by a range of UK and international business. This provides some context for evaluating the potential reductions identified for each of the case-studies.

4.2.3 In considering Inset 19 it should be noted that most of the reductions cited are normalised ("specific"), i.e. they are expressed per unit of product or service delivered. The reductions identified in the Carbon Stewardship Level I scenarios in this study are in effect absolute reductions (because they imply no loss of yield and take no account of potential increases in yield as a result of other developments in the business).

Inset 19: Examples of greenhouse gas emission reductions from non-agricultural sectors and companies in the UK

Aggregate sector: 15% decrease in CO_2 emissions per tonne product 2004 – 2006

Cement sector: 12% decrease in CO_2 emissions per tonne cement 1996 – 2006

Food sector: 9.5% decrease in energy use per tonne product late '90s – 2006

Steel company: 12% absolute reduction in CO_2 emissions 1999 – 2005

4.2.4. Of course, the practices identified in the Level I scenarios are largely of a "one-off" nature; they will not generate repeated, cumulative reductions year on year. But the practices identified are those which have a reasonable level of confidence attached to them and which have been recognised by the research community for some time. If the tone of the Defra[27] report, comments made by suppliers of farm machinery and parallel experience in other industrial sectors are anything to go by, it is not overly optimistic to suggest that each of the case-studies will find scope for further reductions once they have achieved those cited in this study.

4.2.5 But this scope will not be found without help. It can be assumed that every farm business can work out for itself how best to improve the efficiency of its electricity use. With adequate and useable information from machinery manufacturers, it should be as easy (or difficult!) to chose the "right" piece of machinery in terms of carbon stewardship as it has been when the decision was driven by other factors. But doing the right thing to reduce emissions of N_2O and of CH_4 is clearly a very complex subject. This study has relied on the generic advice that may deliver 5% savings in N_2O emissions and up to 90% in CH_4. It is evident from the literature that a lot of research is taking place; it is to be hoped that this will – sooner rather than later – be translated into advice that will help the industry deliver the "next generation" of savings.

4.2.6 A distinction can be made between energy saving practices, which are of interest to virtually all industries, all the public sector and to us all as individual consumers, and practices that reduce emissions of CH_4 and N_2O, which are relevant largely only to farming[c] It is in one sense very encouraging that this study has identified scope for energy saving on farms. But it is in another sense disappointing to find, in 2008, that practices which many non-agricultural businesses would regard as "standard" or "business-as-usual", and about which there is no shortage of advice, are still to be implemented. It is worth pointing out that the main source of information on energy saving practices on farms used in this study was the Carbon Trust (see Inset 2). The case-study businesses were not generally familiar with this organisation or its publications. As far as energy saving is concerned, it would seem that the challenge is not lack of information but failure of outreach and uptake.

[c] The waste management and water industries do share farming's interest in methane as a source of greenhouse emissions, but there are marked differences in the practicalities and the opportunities.

4.2.7 In the case of N_2O and CH_4 we are talking about a need for information that is specific to the industry. Farmers should be looking for and finding existing information that reflects current knowledge about practices they should adopt to reduce emissions of these gases. The best source of such information is the Defra publication of October 2007[28], but there is an urgent job to be done to turn this report into advisory information accessible to farmers. CALM contains some excellent advice, available to all those who take the first step of logging onto the CALM website.
Next, in quick succession, farming will be needing information about practices to adopt to generate the "next generation" of savings; it is to be hoped that such information will by then have emerged from the research which is currently taking place.

4.2.8 The positive comments in section 4.2.2 need to be balanced with a comment on the adequacy of 3 to 10% reductions in the context of where we are now, in early 2008. There is widespread agreement that the UK should now be aiming for reductions of 50% (over 1990 levels) by 2050 and that 80% reductions might be necessary. The leading (non-agricultural) businesses that are on track to achieve their Kyoto commitment of 12.5% by 2010 are now devising their strategies for "fifty by fifty". Farming is a late-starter; some would say that as a sector, it has hardly reached the starting line. The Carbon Stewardship Level I scenarios only demonstrate how four businesses might achieve modest, Kyoto-type reductions in their emissions. Much more is required.

4.3 Carbon Stewardship Level II

4.3.1 The Carbon Stewardship Level II scenarios, designed to reflect more radical course of action, perhaps come closer to reflecting the needs of a low-carbon economy. But it must be stressed again (see section 2.5) that scenarios were identified in discussion with each business and hence each reflects the perspective and the ambitions of the business concerned. They are not low-carbon scenarios per se; they are reflections of what that business sees as possible if a higher priority is given to carbon stewardship.

4.3.2 In Case-study A, the perspective of the business was that there was no scope to go beyond the practice identified in the Level I scenario. In other words, Level I was as far as this business wished to go given the aspirations of the business partners, the current state of commodity and energy markets, and the existence of incentives. Given that the business already delivers a significant degree of carbon stewardship and that the Level I practices are on their way to being implemented, such a perspective seems well-founded.

4.3.3 Case-study B also found that options were limited. Current practice includes many of the practices that are recommended for mitigating greenhouse gas emissions and enthusiasm for anything more radical than allocating 10% of the farm to biomass production was limited by the knowledge that the business achieves consistently high yields per hectare of wheat.

4.3.4 Case-study C has identified an opportunity to focus the business on its principal product range (cut flowers) and at the same time make the business more self-sustaining by using its own land for biomass and its waste products as an energy source. For this to be a viable business model, the customer would have to prepared to pay a premium for flowers produced on a "low-carbon" farm, and/or prices for energy would need to be higher. Both these conditions seem probable. What is less certain is whether Case-study C could be successful in developing the biodigestion (AD) scheme which forms part of the Level II scenario. The scheme envisaged (a partnership with other producers of organic waste) is the one most suitable given the available waste tonnages and other considerations.

Not only does it require other partners and a significant capital investment, but planning permission and waste management licensing would almost certainly be involved. There would therefore be some significant barriers to overcome before the Level II scenario could be realised in practice.

4.3.5 Anaerobic digestion was the practice of choice for Case-study D's Level II scenario. The results confirm that this business could make a significant improvement in its greenhouse gas emissions by adopting this single measure. But it would be a very significant investment for a business of this size and a complex project to embark on. Complexities and risks would be magnified by the need to compensate for lack of scale by entering into a joint venture involving local but not necessarily adjoining businesses. As in Case-study C, we are talking about significant capital investment, a need for planning permission and waste management licensing.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Messages for farmers

5.1.1. In some respects, the findings of this study give grounds for optimism. Farmers should be encouraged by the following points:

- The four case-studies have all found scope to reduce emissions of greenhouse gases from their businesses.
- Some of this reduction has been found in energy saving measures that are well understood, capable of easy management and supported by the drive for more energy-efficient lighting, machinery, fittings etc that is common to all UK business;
- This means that the industry's scope for action is not wholly tied to the complications and uncertainties that arise when trying to reduce emissions of methane and nitrous oxide;
- While the reductions are not large, they are not out of line with the reductions achieved by other sectors of UK business, which have been celebrated by the sectors concerned and are providing a basis for the further reductions now required.
- Estimating the greenhouse gas emissions from a farm using a tool such as CALM will provide an estimate that is good enough for the purpose of understanding those emissions, and beginning to think about their management.
- Using CALM is easy!
- Once a business has used CALM it can tell its customers (e.g. in the next farm assurance questionnaire) that it is doing greenhouse gas (or "carbon") accounting. And if the carbon stewardship practices are put into practice, it can also tell them that it is doing something to manage its greenhouse gas emissions
- There is lots of information out there to help farmers choose and adopt carbon stewardship practices; it does not entail radically different farming methods and there is nothing to stop farmers from getting on with it.
- The scale and the momentum of the shift to a low –carbon economy (in the UK and worldwide) is already supporting such action; it is impossible to conceive that taking action will be seen as anything other than the right thing to do.

5.1.2. But in other respects, the findings of this study should be seen as messages of caution. <u>This is not caution about taking action</u>. It is caution about how the industry positions itself in the fight to combat climate change. Farmers need to be aware:

- The reductions that are possible are unfortunately nowhere near the size and scale we now know we need. The industry is going to have to catch-up <u>and</u> make bigger, further, reductions almost simultaneously.

- The case-studies have demonstrated that the on-farm contribution to sequestration is very small. Farmers should not rely on any notion that farming is all solution and no problem – this is far from the case. The industry's contribution to the solution through sequestration at the moment is small and there does not seem much scope, across farming as a whole, for it to increase. The most promising route seems to lie in adopting techniques to produce food as productively as now, but with much lower emissions of greenhouse gases.

- The techniques for these "next generation savings" are not available right now, but they could and should emerge very quickly. The winners will be those farmers who have already practiced some carbon stewardship, who are asking and listening, and who are ready to move to the next level.

- In the quest for low-carbon farming, farmers need to remember that when it comes to adopting the right practices, they are the customer. They should be asking their advisers and suppliers (not waiting to be told) and they should be proactive in looking for steps that they can take.

5.2. Messages for Government and the industry support network

5.2.1. Current uncertainty about which farm practices do and which do not constitute good carbon stewardship needs to be resolved. This uncertainty is a barrier to action and, equally important, is tending to create a climate in which overly optimistic but speculative practices are getting more attention than they deserve. For instance:

- The Defra report[29] on which this study has relied quite heavily is excellent but not accessible to farming. It should be produced in a practical "guide-to-farmers" format, and made widely available through the usual farming channels.

- Other existing, robust, information could be publicised again; work by the Carbon Trust, for instance, may not have attracted much interest when published but should be given a renewed push.

- All this should be backed up with authoritative statements of the "this is what we don't know" variety.

5.2.2. When a challenge is seemingly huge and many small steps are required, a structure for a staged approach ("stepping stones") can be helpful.

- Government and the industry support network should be working to develop a staged approach to carbon stewardship which farm businesses can follow as their own plan of action.

- This should be supported with clear markers and rewards for progress (perhaps linked to farm assurance).

- The trade associations should consider if and how a commitment to industry or sector progress with this staged approach might be used to galvanise industry action and, if required, as a basis for voluntary agreements of the sort that can operate in place of regulation.

5.2.3. The challenges of methane and nitrous oxide are, by-and-large, specific to the farming sector. Action taken to address these two particular gases has implications for objectives in other areas including water and air quality. Translated into a share of achieving the UK's target for reducing greenhouse gas emissions by 2050, action in this area looks good value for money, meriting investment on behalf of the industry.

- Government must be able to demonstrate that enough effort is going into necessary research and demonstration work.

- The trade associations should be creating the climate in which this is possible, by ensuring the industry demonstrates the appetite and commitment to justify the investment.

REFERENCES

1See http://www.thecarbonfootprintofbritishagriculture.com/

2 See http://www.cla.org.uk/Policy_Work/CALM_Calculator/

3 Defra, 2006. Environmental Key Performance Indicators Reporting Guidelines for UK Business Available at http://www.defra.gov.uk/environment/business/envrp/pdf/envkpi-guidelines.pdf

4 See, for instance, World Business Council for Sustainable Development, 2005. CO2 Accounting and Reporting Standard for the Cement Industry. Available on line at www.wbcsd.org

5 See for instance WRI/WBCSD, 2004. The Greenhouse Gas Protocol; a Reporting and Accounting Standard. Revised Edition Published by World Resources Institute and World Business Council for Sustainable Development Available at: http://www.ghgprotocol.org/files/downloads/Publications/ghg-protocol-revised.pdf

6 EA/NFU, undated. Good Farming Better Environment Published by the Environment Agency and the National Farmers' Union.

7 CLA/NFU/AIC, 2007. Part of the Solution: Climate Change, Agriculture and Land Management. Published in December 2007 by Country Land and Business Association, Agricultural Industries Confederation and National Farmers Union. Available at: http://www.agindustries.org.uk/document.aspx?fn=load&media_id=2926&publicationId=1662

8 http://www.farmingfutures.co.uk/x8.xml
9 Defra, 2007. A Review of Research to Identify Best Practice for Reducing Greenhouse Gases from Agriculture and Land management. Published as the output from project AC0206 and available at: http://sciencesearch.defra.gov.uk/Document.aspx?Document=AC0206_6675_FRA.pdf

10 Carbon Trust, 2006. Agriculture and horticulture Introducing energy saving opportunities for farmers and growers. Available at www.carbontrust.co.uk/energy

11 Carbon Trust, 2006. Energy Use in Pig Farming. Available at:www.carbontrust.co.uk/energy

12 Action Energy, 2002. Energy saving guide for agriculture and horticulture.

13 Carbon Trust, 2006. Agriculture and Horticulture Introducing energy saving opportunities for farmers and growers. Sector overview CTV 009.

14 Carbon Trust, 2006. Agriculture and Horticulture Introducing energy saving opportunities for farmers and growers. Sector overview CTV 009.

15 Carbon Trust, 2006. Agriculture and Horticulture Introducing energy saving opportunities for farmers and growers. Sector overview CTV 009.

16 Carbon Trust, 2006. Agriculture and Horticulture Introducing energy saving opportunities for farmers and growers. Sector overview CTV 009.

17 Carbon Trust, 2006. Agriculture and Horticulture Introducing energy saving opportunities for farmers and growers. Sector overview CTV 009.

18-29 Defra, 2007 ibid