Farming measures for improved CO_2 life cycles of biofuels

Report elaborated in the framework of the Carbon Labelling Project

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Contents

1 Introduction

As part of the EU Carbon Labelling Project, Home Grown Cereals Authority elaborated this report on “Farming measures for improved CO_2 life cycles of biofuels”. This report is based on research funded by HGCA and undertaken by Jeremy Woods, Gareth Brown, Alfred Gathorne-Hardy (Imperial College, London), Roger Sylvester-Bradley, Daniel Kindred (ADAS) and Nigel Mortimer (North Energy Associates). The scientific background reports are available on the HGCA website (www.hgca.com):

- Facilitating carbon (GHG) accreditation schemes for biofuels: feedstock production (2008)
- Understanding and managing uncertainties to improve biofuel GHG emissions calculations (2008)

2 Summary

The research described by Woods et al (2008) and in the Carbon Labelling report on “Carbon Life Cycle Calculation for Biodiesel” shows that substantial reductions in greenhouse gas (GHG) emissions are possible from biodiesel fuel manufactured from UK-produced oil seed rape when substituting mineral diesel. The work has also shown that it is possible to develop and apply the robust and transparent monitoring and calculation methodologies needed to derive credible GHG balances for biodiesel (and bioethanol).

A biofuel GHG calculator[1] has been produced using standardised methodologies and this is now being coupled with on-farm audits. Delivering verifiable supplies of low GHG- emitting biofuel feedstocks requires farm-level monitoring and accounting procedures and tools. The farm auditing presented here provides the basis for such monitoring and accounting, and the resulting GHG calculation tools can be used by farmers to understand and manage their greenhouse gas emissions. The aim is to provide estimates of GHG emissions for individual batches of biofuel feedstocks and to enable farmers to understand and manage those factors which are most sensitive to the GHG emissions.

Based on the evidence-base derived from the farm audits and detailed life-cycle assessment studies from which the GHG calculator has been developed, it has been calculated that it is possible to produce biodiesel in ways that can result in substantially lower GHG emissions than those from fossil fuel-derived diesel: For rape to biodiesel, reductions of between 18% and 39% are calculated[2].

Although further work is required, particularly on indirect impacts, it is clear that the provision of the relevant data by farmers is not overly burdensome or costly and that it can be used to

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[1] https://www.hgca.com/biofuelcalc

[2] Note that the options considered here do not include biodiesel plants powered by CHP which could enable even greater GHG savings to be made

provide sufficiently accurate information to reflect local conditions and management practices.

The HGCA Biofuel GHG calculator highlights the main areas that farmers need to focus on to deliver low carbon feedstocks for biofuel production, in particular to manage nitrogen fertiliser inputs by optimising requirements per unit of output whilst maintaining high yields. Thus:

- Feedstock production accounts for between 50 to over 80% of the total GHG emissions of the biofuel supply chains covered, and is therefore the dominant source of emissions in a biofuel supply chain.

- For biodiesel from rape, nitrogen inputs account for over 90% of the on-farm GHG emissions; nitrous oxide (N_2O) alone accounts for over 60% of those emissions.

- Nitrogen management choices for farmers include sourcing fertiliser from manufacturing plants with nitrous oxide abatement which can reduce feedstock-based emissions by 25-30% (for ammonium nitrate) and selection of varieties with lower nitrogen requirements and are inherently more suited to biofuel production e.g. low protein / high oil rapeseed.

In contrast to nitrogen fertiliser-related emissions, on-farm fuel, pesticide and seed supply-based emissions account for about 20% of the total farm-emissions and some gains could be made here, for instance, by minimising cultivation operations. Other areas which could have a significant impact on farm emissions are land–use history, soil type and timing of field-operations, particularly nitrogen fertiliser applications and any drying operations.

Much of the reduction potential in GHG emissions from biofuels results from the way energy is produced and used in the biofuel conversion plants. The most substantial reductions in emissions result where co-products are used to produce heat and surplus electricity. However, much work is still to be done to clarify the GHG impacts of alternative uses of co- and by-products, particularly when used as animal feed. Despite this uncertainty, as energy use and GHG emission efficiencies are raised in the conversion plants, pressure will mount on farmers to deliver lower GHG-emission feedstocks.

Agriculture, therefore, has a critical role to play in ensuring that biofuels can provide a robust tool for climate change mitigation. However, to be credible, there is an urgent need for simple, practical and verifiable tools that allow farmers to focus on the main components of biofuel supply chains over which they have control. This work has delivered a standardised, transparent and clear methodology for calculating both farm and whole-chain biofuel supply GHG balances. It has developed an integrated GHG calculator for biodiesel from rape (and bioethanol from wheat) and a new electronic questionnaire for farm audits. By carrying out these activities, a major step towards on-farm GHG certification has been taken and near-term future developments should lead to a simple, robust and transparent audit questionnaire for direct use in biofuel feedstock assurance and certification.

Land constraints may prevent a substantial share of the EU's transport fuels being obtained from indigenously supplied biofuels. However, there is an opportunity for EU farmers to demonstrate how efficient agriculture can deliver low GHG emitting biofuels enabling them to be competitive in an emerging global market that rewards such low GHG options and satisfying Renewable Transport Fuel Obligation (RTFO) and EU Renewable Energy Directive (RED) requirements.

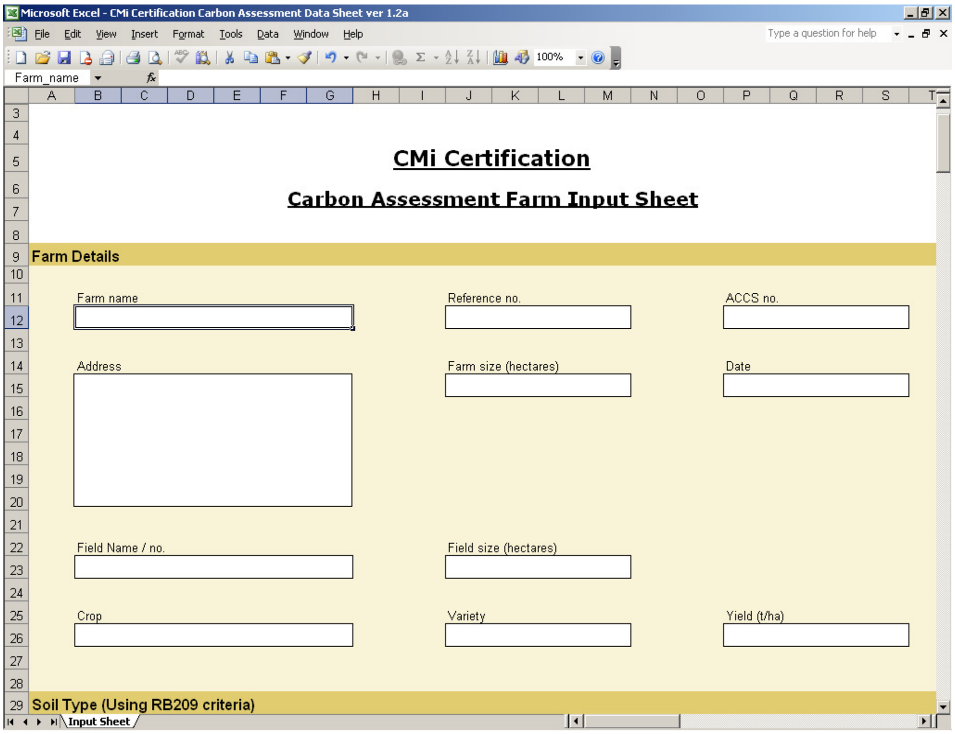
3 Farm audits

In the Carbon Labelling report on “Carbon Life Cycle Calculation for Biodiesel” a description was given of the HGCA Biofuels GHG calculator, a spreadsheet-based tool for calculating the GHG emissions resulting from the production and use of wheat-based bioethanol or rapeseed biodiesel in the United Kingdom (Woods et al 2008). Alongside development of the calculator, farm audits have been developed, as a possible ‘bolt-on’ to the Assured Combinable Crops Scheme (ACCS) audits, with the aim of allowing the GHG emissions associated with the feedstock production for biofuels to be calculated at the farm-level. To date, two years of audits have been carried out by the auditing body CMi using questionnaires developed in collaboration with Imperial College London. The following sections provide an overview of the rationale and key findings from the farm audits.

3.1 Overview of approach

In March and April 2007, CMi carried out ca.100 farm surveys on wheat and oil seed rape (OSR) production in locations throughout England which were administered in conjunction with ACCS audits. The audits covered production data for the 2005/06 season. These audits follow on from those carried out the previous year with data from the 2004/05 season. Fifty-seven surveys were collected in 2006 including spring and winter sown wheat and oil seed rape.

A significant change for the 2007 audit was the development and use of an electronic version of the questionnaire (Figure 1). This is an important development, as it is planned that future audit data will be inputted automatically to the Greenhouse Gas Calculator, improving the accuracy and efficiency of obtaining GHG emission levels from individual farms/fields.



CMi Certification

Carbon Assessment Farm Input Sheet

Farm Details

Farm name

Reference no.

ACCS no.

Address

Farm size (hectares)

Date

Field Name / no.

Field size (hectares)

Crop

Variety

Yield (t/ha)

Soil Type (Using RB209 criteria)

Figure 1: Farm audit sheet for the 2007 audit

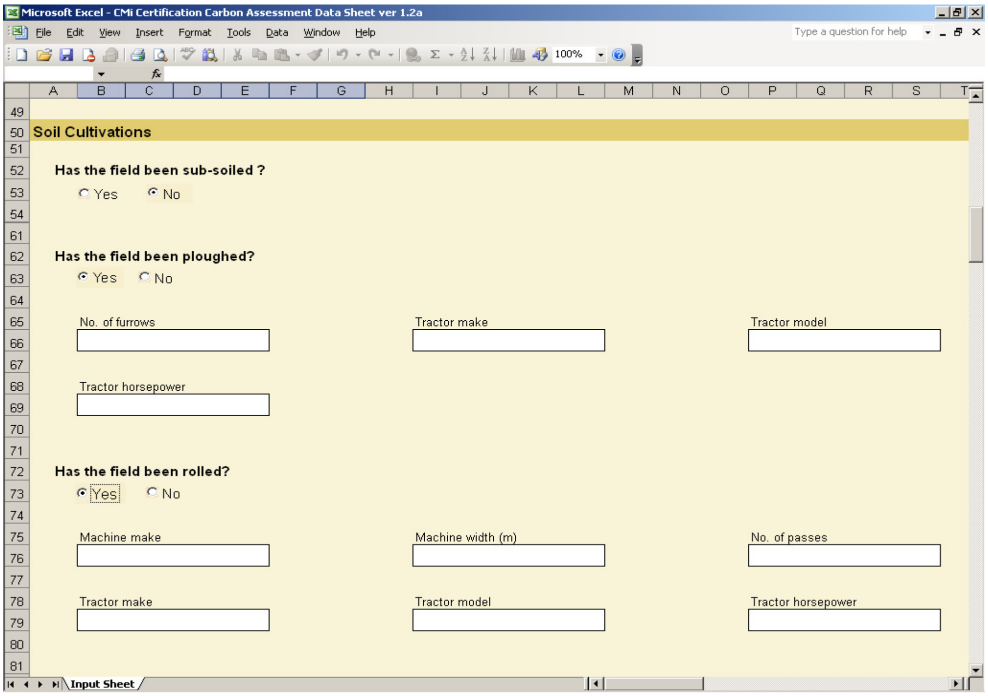
3.2 Audit questions

The farm audits ask a number of questions about the farming conditions and operations involved in production of biofuel crops on particular fields or farms. It is important to note that the current audit sheet *is not* necessarily the final version. For this stage of the project it was decided to ask a broad, but practical range of questions. The questions were developed in order to assess the practicability of this approach to farm-level GHG emission calculations and to choose the areas that are most sensitive to farm management practices and therefore amenable to change should carbon management become a cost-effective option in the future.

When choosing the specific questions, a balanced approach has been developed between the desire to obtain the 'ideal' information required to calculate a detailed GHG emissions factor and the limits of what information is reasonably likely to be available from farmers.

3.2.1 Cultivations

Cultivations have both direct and indirect impacts on GHG emissions. Direct emissions from diesel use are approximately 10% of on-farm emissions. The main energy expenditure associated with soil cultivations is determined by the physical mass of soil moved, so diesel use is expected to be independent of engine size. For a specific field the energy demanded for cultivations is dependent on many factors including recent weather and soil type, but the only easily available data to collect is the soil type, as discussed later. The different operations also have indirect GHG emission implications, for example ploughing increases the rate of SOC (Soil Organic Carbon) oxidation compared to minimum tillage, suggesting that minimum tillage reduces GHG emissions. Yet ploughing every four years or so in the rotation to control grass weeds is thought to release the majority of C stored during the minimum tillage years. This is discussed in detail in Kindred et al (2008). The effects of ploughing on N_2O emissions are even less well understood, and due to the high levels of uncertainties surrounding these factors they are not presently used in the GHG calculator.



Soil Cultivations

Has the field been sub-soiled ?

○ Yes ● No

Has the field been ploughed?

● Yes ○ No

No. of furrows

Tractor make

Tractor model

Tractor horsepower

Has the field been rolled?

● Yes ○ No

Machine make

Machine width (m)

No. of passes

Tractor make

Tractor model

Tractor horsepower

Figure 2: Cultivation input section of audit sheet

3.2.2 Soil type

A critical change in the 2007 surveys (for 2006 yields) was a more detailed question about soil type. Previously this had been asked as an open ended question, and the answers varied widely and could not be compared. To solve this problem farmers were asked to assess their soils according to the 7 types listed in RB209 (Table 1).

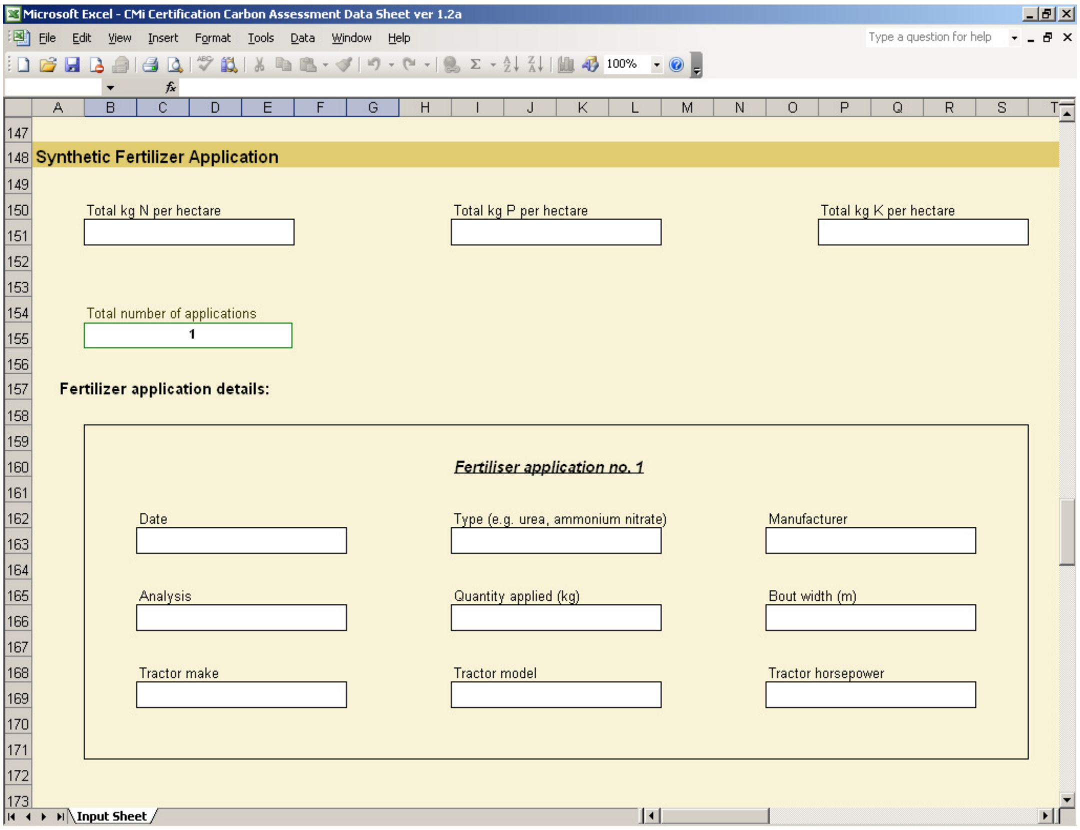
This information is useful because it may enable a more precise, batch-specific calculation of on-farm N_2O emissions and cultivation energy requirements, two factors which have so far only been calculated on a regional basis or by using uncertain default factors:

Table 1: The different soil types used in the farm audits (Source: RB209)

Light sand soils	Soils which are sand, loamy sand or sandy loam to 40 cm depth and are sand or loamy sand between 40 and 80 cm, or over sandstone rock.
Shallow soils	Soils over chalk, limestone or other rock where the parent material is within 40 cm of the soil surface. Sandy soils developed over sandstone rock should be regarded as light sand soils.
Medium soils	Medium textured mineral soils that do not fall into any other soil category.
Deep clay soils	Soils with predominantly sandy clay loam, silty clay loam, clay loam, sandy clay, silty clay or clay topsoil overlying clay subsoil. Deep clay soils normally need artificial field drainage.
Deep fertile silty soils	Soils of sandy silt loam, silt loam to silty clay loam textures to 100 cm depth or more. Silt soils formed on marine alluvium, warp soils (formed on river alluvium) and brickearth soils (formed on wind blown material) will be in this category.
Organic soils	Soils that are predominantly mineral with between 6 and 20% organic matter. These can be distinguished by darker colouring that stains the fingers black or grey and gives the soil a silty feel.
Peaty soils	Soils that contain more than 20% organic matter derived from sedge or similar peat material.

3.2.3 Fertiliser usage

There are three important factors affecting GHG emissions from agricultural fertiliser use – the embodied GHG emissions of the products, the field GHG emissions, and diesel use in application. The emission from diesel is a small fraction compared to the other two factors, which are discussed in detail in Kindred, et al (2008). The audits ask not only the total quantity of each fertiliser applied, but also the type and timing of application, as these have important GHG implications for the embodied and in-field emissions respectively.



Synthetic Fertilizer Application

Total kg N per hectare

Total kg P per hectare

Total kg K per hectare

Total number of applications: 1

Fertilizer application details:

Fertiliser application no. 1

Date

Type (e.g. urea, ammonium nitrate)

Manufacturer

Analysis

Quantity applied (kg)

Bout width (m)

Tractor make

Tractor model

Tractor horsepower

Figure 3: Fertiliser input section of audit sheet

3.2.4 Pesticide usage

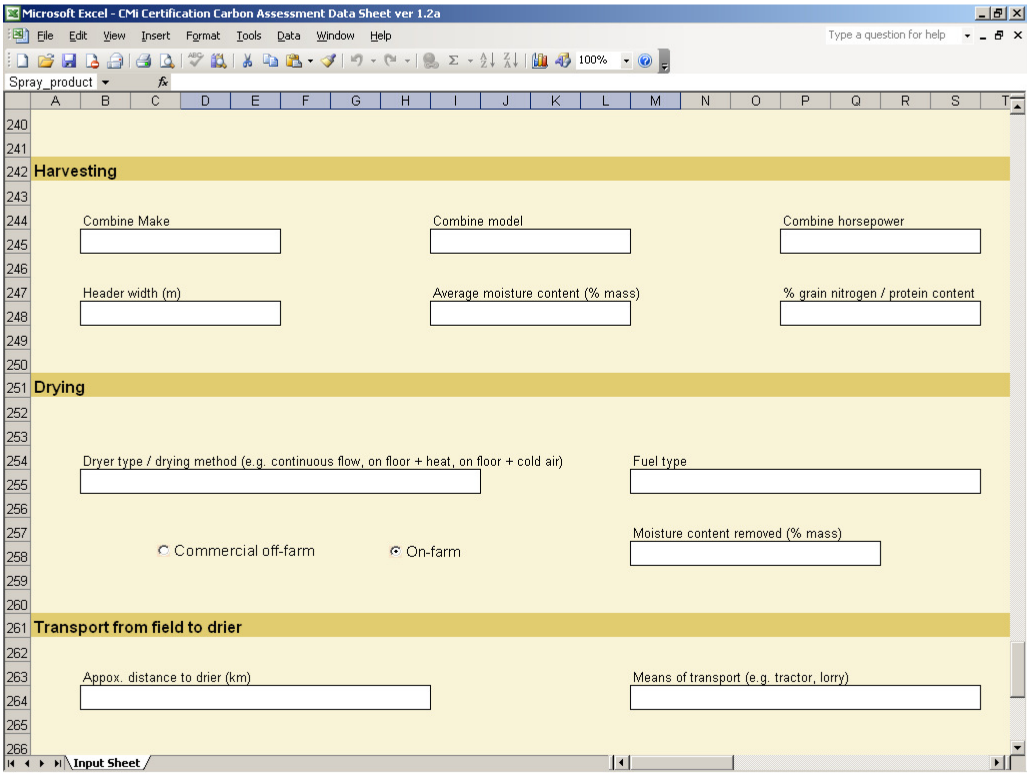
There are two GHG implications of pesticide use, the embodied energy of the products, and the diesel required in their application. Diesel use is calculated through the number of applications. The embodied energy is harder to calculate. There is a poor data set for the embodied energy contained in different pesticides, most of the literature relies on or extrapolates from a single piece of dated research. Using averages for different pesticide groups (already a large generalisation), calculations show that pesticides equal a very small percentage (less than 1%) of the on-farm emissions. Due to the unreliability of the original data together with low GHG emissions levels associated with pesticide use, pesticides are ignored from these calculations as their emissions are well within the range of uncertainty. The number of passes that the sprayer makes is used to calculate the diesel used. Detailed pesticide data is still recorded for two reasons – if better information becomes available then this data can be retrospectively used, and the data could be useful for bio-fuel sustainability certification.

3.2.5 Grain nitrogen

This is recorded as a potential future source of information on the efficiency of N uptake by the plant, and indirectly the level of N application, but as yet this area is under-researched.

3.2.6 Grain drying

Grain may be taken off the field at a variety of moisture levels, but must be reduced to 9% moisture for OSR for safe storage. Moisture reduction can occur through a variety of mechanisms, but most commonly used are continuous flow, on floor and batch driers. The amount of energy required depends on the drying method, process and percentage of moisture to be removed.



Harvesting

Combine Make

Combine model

Combine horsepower

Header width (m)

Average moisture content (% mass)

% grain nitrogen / protein content

Drying

Dryer type / drying method (e.g. continuous flow, on floor + heat, on floor + cold air)

Fuel type

○ Commercial off-farm ● On-farm

Moisture content removed (% mass)

Transport from field to drier

Appox. distance to drier (km)

Means of transport (e.g. tractor, lorry)

Figure 4: Audit sheet inputs for feedstock harvesting, drying and transport [3]

3.3 Results

Table 1 shows a selection of farm audit data results, such as mean and standard deviations of different parameters.

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[3] The full audit sheet is available at http://www.hgca.com.

Table 2: A selection of farm audit data results (* after drying to storage moisture content)

	OSR	
	Mean	Standard deviation
Feedstock yield*(t/ha)	**3.55**	0.762
N (kg/ha)	**191.8**	34.7
P (kg/ha)	**42.5**	n/a
K (kg/ha)	**42.2**	n/a
Manure applications	**9**	n/a
Moisture content (%) after drying	**8.59**	3.121
Moisture removed (%)	**1.2**	1.8
Distance to dryer (km)	**2.28**	2.23

3.3.1 Fertiliser use

Fertiliser use is the most significant GHG contribution to the production of biofuel crops, accounting for around 90% of emissions. Of all the fertilisers, N is by far the most important, accounting for 96% of fertiliser GHG emissions in the 2007 data (95% in 2006), compared to just 1% and 2% for P and K respectively. The relationship between fertiliser applied and the emission of N_2O is complicated, with factors depending on soil type, agricultural practices (including cropping) and local weather and climate, but in these calculations we will assume a direct relationship using IPCC data.

3.3.2 Nitrogen use

From the 100 farm surveys carried out by CMi on wheat and rape production, covering the 2005/06 season, N fertiliser additions for wheat ranged from 90 – 283kg/ha, with an average of 194kg/ha (compared to 80 – 300 kg/ha, mean 186kg/ha in 2004/05 data). As Figures 5 and 6 show, there is no obvious relationship between N applications and soil type except in the organic soils, soil type 6. Organic soils received about a third less N than other soils ($p<0.05$), yet there is no significant difference in the yield between soil types (Figures 7 and 8). No farmers classified their fields as 'peaty', so we have no data from soil type 7 for wheat or OSR.

To demonstrate the importance of N, the Greenhouse Gas Calculator has been used to compare the results between the highest and lowest N users. This comparison can be described by the following issues:

- Farm 1507 applied 283kg N, 92kg P and 108kg K per ha and had a yield of 11.2t per ha.
- Farm 3507 applied the least N (90kg/ha), applied no P or K, had a yield of 8.3t per ha.
- Neither farm applied manure.
- The results show that the wheat grown using 90 kgN/ha had a 38% GHG reduction compared to petrol, whilst the 283 kgN/ha wheat had only a 28% reduction in GHG emissions compared to petrol. It should be noted that these are estimated whole chain (so called Well-to-Tank) calculations and assume an identical process chain.

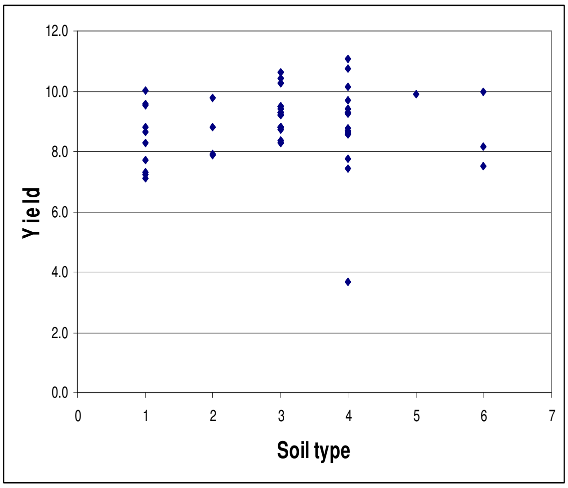

Figure 5: Wheat yield according to soil type

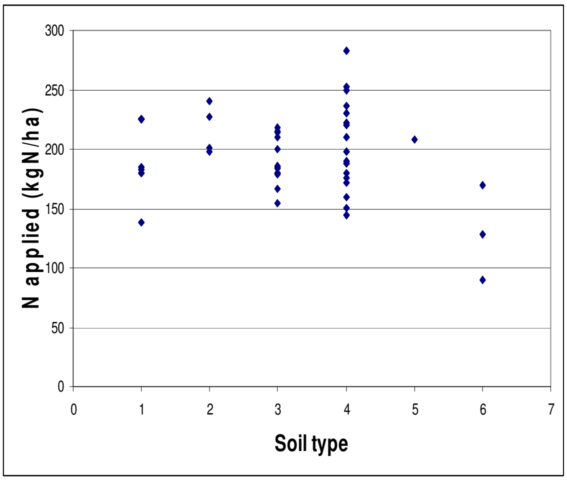

Figure 6: The fertiliser applied per hectare

This constant yield together with lower N application rates for the organic soils, using present calculation methods, gives a significantly lower GHG emissions per tonne from wheat grown on organic soils compared to the other soils ($p=<0.05$). Organic and peaty soils allow farmers to apply lower levels of fertiliser through high nitrate retention, and more importantly because the soils *supply* N as the organic/peaty elements degrade. Thus the farmer is effectively mining N from organic soils, and importantly the N_2O released during this process (as well as the CO_2) is not accounted for in the figures supplied here, but could make an important contribution to the actual GHG emissions. Similar results apply for OSR (N fertiliser application ranged from 100-270kg/ha with a mean of 189 kg/ha).

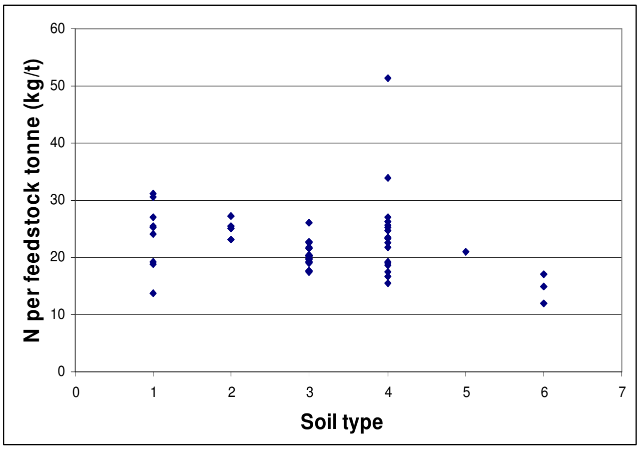

Figure 7: Nitrogen application per feedstock tonne (wheat)

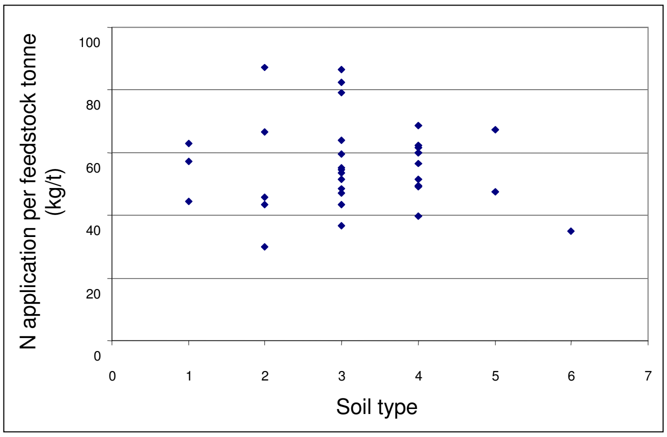

Figure 8: Nitrogen application per feedstock tonne (OSR)

3.3.3 Phosphorous and potassium use

As expected there is large variation in use, as this depends greatly on alternative fertilisers applied (e.g. manure and/or mineral fertilisers), the fate of straw, and how much was applied in previous years. Almost half of the farmers applied no P and/or K in the audited year (2005/06 season), slightly more than the previous year (40%). From the GHG perspective these fertilisers are less significant than N, although they have important wider sustainability implications, for example P is the main source of eutrophication in inland UK waters.

3.3.4 Manure applications

In total 14 fields had manure applied. A decrease in synthetic N application levels is expected with manure applications, and a significant reduction was seen in wheat (mean 171kg/N/ha with manure applications, to 188kg/N/ha with no manure applications ($p<0.01$)). In contrast, there was a (non-significant) rise in synthetic N application when manure was applied to OSR, from 188 to 201kg/ha, when manure was not applied and was applied respectively. Further work is required to understand the longer term impacts of manure use on soil organic matter levels and therefore on nutrient and soil water holding capacity which could affect yields and application rates of mineral fertilisers.

3.3.5 Cultivation operations

Diesel use is (normally) the second most important source of GHG emissions in the biofuel production chains assessed. Based on the 2005/06 farm audit data, diesel use accounts for approximately 6% of total GHG emissions for production of OSR. These figures vary widely according to the chosen operations, for example in OSR, the GHG emissions associated with cultivations range from 3-16% of the total. Not included in these calculations is the potential for GHG sequestration through choice of cultivation techniques. These points are discussed in more detail in Kindred, et al (2008).

There are different options for calculating the diesel use; hour based calculations, or work based. In this report we have used both, but recognise serious short comings in each. For the hour-based analysis, approximate hours to carry out a cultivation on a hectare were used, and this was converted into diesel use through combining with the size of the machine, and diesel use figures from Nix's The Farm Management Pocketbook, and finally using a multiplier to accommodate for soil type. The problems with this method include poor initial data sets, especially the poor reliability of data for hour-based tasks. More commonly used in the literature are work based calculations, the energy required, for example, to plough a hectare. Unfortunately these are often based on limited data sets, and rarely take account of different soil types. The analysis of 2007 farm audits are based on calculations derived by amassing many previous calculations of diesel use from the literature, and dividing this by the spread of soil types we have used. So soil type1 (light and sandy soil) correlates with the lowest recorded figures while soil type 4 (deep clay soil) requires the most. Other soil types were graded between these two scores.

A further problem with assessing diesel requirements for cultivation is the range of equipment available for use; it is hard to categorise many of the machines now available on the market. Although diesel use for cultivation is relatively minor in terms of GHG emissions, further work is required to ensure that this is the case and to minimise the uncertainty currently associated with these calculations.

Our results showed no significant trend between different soil types and specific operations and, as expected, individual operation types represented only very low percentages of the total GHG emissions. For example ploughing wheat, when it occurs (45% of total in 2004/05, 41% in 2005/06) was responsible for 4.5% of the overall GHG emissions, while sub-soiling the tramlines was only 0.6%. Yet the impacts not yet accounted for; the effect of cultivation on soil N and CO_2 fluxes could increase the importance of cultivation in the overall GHG balance of biofuel feedstock. As a management practice that is amenable to change it is important to continue using this area in the calculations.

3.3.6 Grain drying

Moisture reduction can occur through a variety of mechanisms, but most commonly used are continuous flow, on floor and batch driers. The amount of energy required depends on the drying method, process and percentage of moisture to be removed. According to Mortimer et al 2003, drying is as important in terms of GHG emissions as the impact of cultivation regime. Opportunities to reduce GHG emissions either through changes in drying system, harvesting time or through consolidated drying should be considered.

3.4 Conclusions on farm audits

The farm audits have been developed with two questions in mind, what information we would *like* from farmers, and what information can reasonably be *collected* from farmers. The audits have highlighted the large diversity in management approaches, input requirements and monitoring activities that occur on UK-farms. Despite this diversity it is possible to obtain most, if not all, of the relevant data required to calculate a robust GHG balance for biofuel feedstocks. Furthermore, a number of factors which affect the accuracy and confidence in the calculations are outside the capacity or control of farmers to influence and will require alternative mechanisms to gather and analyse the data required. Such factors include indirect land-use and direct and indirect nitrous oxide emissions.

The most influential GHG emissions factor, N fertiliser application rate, is highly variable. There is a pattern that, for organic soils, N fertiliser rates are significantly reduced, possibly due to the higher N levels present in the soil. However, the gains from the resulting lower emissions may need to be offset by increased carbon-based emissions resulting from the oxidation of the SOC in these high-organic-matter soils.

Cultivation options show no apparent relationship between soil or crop type, but are likely to be determined by previous cultivations, as well as local preferences / situations / habits. Using present GHG emission calculations, cultivation has relatively low emission factors, but further research on the role of cultivation in soil CO_2 and N_2O fluxes might alter this.

When more accurate information on the implications of different cultivation regimes, soil types and fertilisers is available, the audit system, together with the calculator, will allow accurate GHG assessments of each feedstock tonne. With this in mind, the next two steps are to allow farmers to 'virtually' farm their land, experimenting with different practices to create the lowest possible 'carbon tonne' of feedstock fuel, and also to potentially widen the scope of the audit system to include the whole farm, as discussed in Kindred, et al (2008).

4 Potential developments in biofuel crop production

Some potential future developments in biofuel crop production are considered including how these may impact on total GHG emissions as well as options in which monitoring and reporting schemes may be developed to act as incentives to induce changes that reduce emissions.

4.1 Crop breeding

The emergence of biofuels as a new market for crops is likely to stimulate crop breeders to breed crop varieties specifically suited to the biofuel process, both in terms of crop quality and agronomy.

4.1.1 Breeding for improved crop quality and processability

For biofuel production the crop requirements are for low protein / high starch (bioethanol) or high oil (biodiesel) content. Breeding for low protein/high starch varieties is likely to be relatively straight forward, as protein is easily and routinely measured, and good genetic variation for it is known to exist. There is a good chance that breeding for reduced protein content will be successful, as this is the opposite of the main breeding target for the past 30 years, namely high protein content for bread and biscuit making.

For oilseed rape, breeding for biodiesel use is little different to breeding for conventional end markets; in both cases the important quality trait is oil content. Breeders improved oil content of the seed from under 40% to around 44% by the 1990s (Spink & Berry, 2004; Berry & Spink, 2006) but there has been little increase since then, suggesting that the scope for further improvement may be limited. As well as oil content, breeding efforts seek to improve oil quality (e.g. fatty acid composition) for specific markets, and biodiesel is likely to be no exception. Whilst better oil quality may improve the final quality of the biofuel, it is unlikely to give significant improvements in the GHG intensity of the final biofuel through reduced energy costs in processing.

4.1.2 Breeding for improved agronomic performance

As well as breeding for improved grain/seed quality for the biofuel market, it is also likely that breeding will improve agronomic characters of crops for biofuels which may affect the GHG intensity. Most simply, continued crop yield improvements from breeding should improve the GHG intensities of the resulting biofuel. Whilst higher yields from crop breeding may be associated with higher crop inputs per ha, the main research target should focus on decreasing GHG emissions per unit output and not on gross yields or inputs.

As the major GHG cost of crop production involves N fertiliser, any crop breeding improvement that reduces the crop's need for fertiliser could be of major benefit in producing low GHG intensity biofuels. Because use for biofuels requires the high energy carbon rich portions of the seed (e.g. oil for biodiesel) and not the protein component, there is a more limited need for nitrogen as protein in the seed. This may give the opportunity to reduce the N requirement for the crop as a whole, if yields can be maintained with reduced N content in the crop canopy. A LINK project sponsored by Defra is specifically looking to facilitate the breeding of oilseed rape varieties with reduced N fertiliser requirements by identifying nitrogen 'stores' in the crop and seeking genotypes with reduced stores. Breeding for traits such as reduced N requirements is unlikely to be straightforward, and it seems unlikely that varieties requiring significantly less N fertiliser will be available commercially within the next five years.

4.2 Premium schemes

It is likely that as the biofuel industry develops, premiums will be paid for feedstocks that are of greater value. This is already the case for oilseed rape where premiums are usually given for high oil content. Such premiums would encourage farmers to grow crops that are most appropriate for biofuel use, both in terms of the varieties grown and crop management. Premiums would also encourage the development of new varieties as discussed above.

4.2.1 Premiums for feedstock quality

The most important management factor that farmers can influence to improve the potential biofuel yield is nitrogen fertiliser application. Applying N fertiliser increases protein content of the grain, and hence reduces starch content and alcohol yield (Smith et al., 2006; Kindred et al., 2007b). The relation between N fertiliser and alcohol yield per ha is investigated in detail in HGCA Project Report 417 (Kindred et al., 2007a). This suggests that the economic optimum N fertiliser rate for alcohol yield per ha is around 12% lower than that for grain yield, assuming that the bioethanol processor was also growing the crop. In commercial reality the N rate that a grower applies to a biofuel crop will depend on the premium available, if any. Given that low protein wheat may be worth considerably more to a bioethanol processor, both because of the higher likely alcohol yield and reduced processing costs as described above and, given that lower protein grain can be achieved with reduced N fertiliser applications, it is likely that premiums for low protein/high starch/high alcohol yield wheat grain would result in reduced fertiliser rates by growers. In this case the GHG intensity of the biofuel may be improved, both by improved processing efficiency and reduced GHG emissions from reduced fertiliser use.

It may also be argued that general increases in crop prices, partly due to increased demand from biofuels, may lead to increased productivity and greater yields with minimal increases in inputs. Whilst crop prices have been relatively low for the past 10 years there has been little evidence that on-farm yields in the UK have increased, despite there seeming to be continued yield improvements with new varieties.

4.2.2 Premiums for low GHG feedstocks

With the onset of Carbon Reporting in the UK RTFO and the EU RED, a subsequent move to targets based on GHG reductions the carbon intensity of the biofuel will become increasingly important in economic terms, and it is possible that feedstocks with a lower GHG intensity will be more valuable to the processor. In such a case, premiums could be paid for crops that have a low GHG intensity, and farmers could be rewarded for practices that produce crops with low GHG costs. Again, given the importance of N fertiliser to the overall GHG intensity, it is likely that nitrogen would be the main management factor to be affected by such considerations.

Kindred et al. (2007a) have conducted a preliminary analysis of how GHG costs of a biofuel change with N fertiliser application. This suggests that the GHG intensity of the biofuel is lowest when no fertiliser is applied. However, accepting that biofuel production, and hence savings against fossil fuels, is limited by the amount of land available, it may be argued that it is the potential GHG savings per ha of land which is of most importance. N fertiliser initially increases GHG savings per ha as yields per ha and hence biofuel production increase. However, the initial findings of Kindred et al (2007a) suggest that the GHG savings per ha for wheat for bioethanol begin to decline after applications of around 100kg N/ha. This would suggest that, if the prime objective of biofuels is to reduce GHG emissions, that N applications to biofuel crops should be significantly reduced. There is a need to conduct these analyses more thoroughly, considering the economic costs (in terms of yield foregone) of reducing the N fertiliser rate to that which optimises GHG savings, rather than grain yield.

It seems likely that if reasonable premiums were available to incentivise the production of crops with reduced GHG emissions there would be scope for significant reductions in N fertiliser applications by growers.

For growers to be able to contribute to reduced GHG intensity of biofuels by reducing N fertiliser application, and to benefit from this economically, it will be necessary for growers to demonstrate what the application rate has been, and for this to be verifiable.

4.2.3 Effects of low-GHG premiums on the farming system

As well as impacting on fertiliser use, it is possible that economic incentives to produce feedstocks with low GHG intensities would encourage growers to change other parts of the farming system.

It is possible that different fertiliser products have substantially different GHG costs. It is possible that growers could choose to use fertiliser products with lower GHG emissions (perhaps due to N_2O abatement technologies) which would result in a lower GHG intensity for the crop. Such a situation could encourage fertiliser manufacturers to report on the GHG intensity of their products. For growers and fertiliser manufacturers to benefit from these reduced GHG emissions it would be necessary to allow the emission factor of the fertiliser used to be specified in the carbon reporting methodology.

It may be appropriate that cultivation practices that use less fossil energy should be rewarded with lower calculated GHG emissions. This could potentially encourage the development and uptake of machinery and practices that require less energy, such as minimum tillage. To enable these differences to be accounted for in carbon reporting, a way of estimating diesel use on-farm would be needed, as discussed in section **3.3.5** and Kindred et al (2008). This would need to be backed up with robust information on the diesel use of different cultivation methods, which may require in-field experiments and measurement.

4.3 Conclusions on future developments

Whilst it is not possible to predict all the future developments likely to face the arable industry in the coming years, or to predict the possible ramifications of the emerging biofuel industry and carbon reporting, it is clear that given the right incentives, growers and the wider agricultural industry could make changes that would improve the GHG intensity of crops and the resulting biofuels. In order for these improvements to be made it will be important that the carbon / GHG reporting methodology allows for these changes to be fully accounted for. In turn, farmers need to know the conditions (climate, soils and management) under which the least-cost gains can be made.

Crop breeding and changes to fertiliser manufacture and application to land appear to provide the biggest and most immediate opportunities for improving GHG intensities. Whilst changes to yield and N fertiliser input can easily be accounted for in the GHG reporting methodology, as they are key input values; more subtle effects on biofuel processing efficiency are less easily accounted for.

Most of the changes that improve the GHG intensity of biofuel crops are equally applicable to reducing GHG emissions from arable cropping in general. It is possible that economic incentives to farmers could transpire through carbon trading mechanisms. The potential for this is being investigated in Defra project SFF0602.

For farmers to gain from the emerging policies directed at reducing GHG emissions on a national basis e.g. the Renewable Transport Fuels Obligation (RTFO) and the UK and European Emissions Trading Schemes (ETS), the sector needs to demonstrate transparent and practical methodologies for accounting for GHG emissions. The work highlighted here provides a pathway for delivering such an accounting system.

5 Overall conclusions

In order to maximise the potential benefits of a EU biofuels industry, and in particular to maximise GHG savings, there is a need to promote farm-level reporting of GHG emissions. The aim of this reporting would be to allow a share of the value arising from avoided GHG emissions to be retained by growers and to incentivise continued improvements in GHG intensity of biofuel crop production. The parallel development of the science-base and the practical tools necessary to implement farm-level GHG auditing are also required.

This work has shown that whilst there are a range of important issues that remain to be resolved before farm-level GHG (carbon) reporting can become basic farming practice, these issues are not insurmountable. The farm audit trials and development of the calculator show that it is possible to use data obtained directly from farms to get credible individual GHG intensities. The resulting improved levels of accuracy of reported GHG emissions will be incentivised in the UK RTFO through adoption of conservative default values for GHG intensities (E4Tech, 2006).

Continued development of the farm audits is necessary to demonstrate to the farming and biofuel production communities that the collection, compilation and evaluation of farm-level data are both practical and accurate.

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