

Implications for UK Farmers of greenhouse gas reporting under the Renewable Transport Fuel Obligation

J. WOODS & A GATHORNE-HARDY

Porter Institute / CEP, Imperial College London, SW7 2AZ

Summary

As the science underpinning man's influence on climate change becomes more certain, the opportunities and threats for agriculture in the UK have become more apparent. Earlier research work funded by the HGCA and by other agencies began the process of:

1. developing the confidence that annual crops could be used to produce biofuels which under the right circumstances, result in significant reductions in greenhouse gas (GHG) emissions when used to substitute for fossil fuels in transport;
2. reducing the range in the uncertainties associated with the claimed climate change mitigation benefits of biofuels;
3. developing the tools necessary to show individual farmers how their own farming practices affect, and can be changed to reduce, the GHG emissions associated with biofuel feedstock production.

This paper outlines the potential application of these tools as part of the reporting process for the UK Renewable Transport Fuels Obligation. It is based on the outcomes of 'Facilitating carbon (GHG) accreditation schemes for biofuels: feedstock production.' The project resulted from collaboration between Imperial College London (Jeremy Woods, Gareth Brown and Alfred Gathorne-Hardy), ADAS (Daniel Kindred and Roger Sylvester-Bradley) and North Energy (Nigel Mortimer).

Introduction

The main objectives of this project were to:

- i. Scope the potential for technological improvement of biofuel feedstock production in terms of GHG emissions.
- ii. Scope the uncertainties surrounding the quantification of on-farm factors affecting GHG emissions from wheat and OSR for biofuel production.
- iii. Develop methods for converting farm audit information into estimates of GHG emissions.
- iv. Recommend the best approaches for dealing with issues reviewed in (ii) for carbon accreditation schemes and highlight future research requirements.
- v. Inform the RTFO process and further development of carbon reporting and accreditation.

In order to achieve these objectives the project activities were divided into four discrete but linked activities led by the individual partners in the project. These activities have resulted in five main outputs as follows:

1. A revised GHG calculator (Excel based spreadsheet) which provides a standardised methodology and tool for calculating the life-cycle GHG emissions from:
 - a. UK-based wheat to ethanol
 - b. UK-based rape to biodieselThe new version of the GHG calculator was demonstrated at Cereals 2007 and is available on the HGCA website: <http://www.hgca.com>. This work has been an essential part of meeting objective 'ii' above, but also 'iv' and 'v'.
2. This report which includes:
 - a. A detailed evaluation of the 'uncertainties' which currently fuel the controversy surrounding biofuel implementation and their role as a practical tool for GHG mitigation at the national and global scales. Developing the methodologies to firstly reduce, and secondly manage these uncertainties is a core part of this research and is critical to the development of a sustainable and publicly acceptable biofuel industry. The outcomes of the evaluation of uncertainty have therefore played a role in meeting all the objectives of the project, particularly objective 'i' and 'ii'.
 - b. An evaluation of the 2 years of farm audits carried out as a 'bolt-on' to ACCS and recommendations for future improvements and implementation strategies. The development of practical and simple farm audit questionnaires and monitoring schemes has provided a number of recommendations for objectives 'iii', 'iv' and 'v'. The work has also played a role in meeting objectives 'i' and 'ii'.
3. Recommendations for new research work to address the uncertainties and bottlenecks identified and to develop the practical steps necessary to move towards on-farm GHG reporting.
4. A major display at Cereals 2007 demonstrating the new version of the GHG calculator.
5. Close and continuing technical interaction with RTFO methodology development.

Results

Understanding how to manage and reduce the uncertainties in GHG balance calculations for bio-products, including biofuels, will be critical to obtaining credible and, therefore publically accepted, GHG reduction factors for biofuels. The analysis of, and options to overcome or mitigate, those uncertainties is extremely complex and diverse, and is covered in detail in a separate report produced as part of this project (Kindred et al, 2007c).

This work highlights that:

- Real gains are possible in reducing GHG emissions from UK feedstock-derived biofuels (i.e. ethanol from wheat and biodiesel from rape).
- On current evidence, it is possible to produce those biofuels in ways that can result in substantially lower GHG emissions than their fossil fuel surrogates:

- For wheat to ethanol, reductions of between 10 and 95% are calculated using standard UK-average agricultural factors and a range of conversion plant configuration options.
- For rape to biodiesel, reductions of between 36 and 66% are calculated.
- Substantial uncertainties exist both in the GHG accounting procedures and in the wider sustainability analysis. These uncertainties result from both, the complexity of potential biofuel supply chains and in the scientific understanding of some of the mechanisms that result in the production of GHGs.
 - Tools to understand and manage the uncertainty are playing a major role in progressing towards sustainable land management (including for biofuels, food and materials). Such tools represent a key component of climate change mitigation and adaptation strategies for the agriculture and forestry sectors and include the GHG Calculator outlined below.
- Major reductions are possible, particularly through understanding and optimising the use of inputs, particularly nitrogen:
 - 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.
 - For biodiesel from rape, nitrogen inputs account for over 90% of the on-farm GHG emissions. For ethanol from wheat, nitrogen use accounts for 80% of the on-farm emissions; nitrous oxide (N₂O) alone accounts for over 60% of those farm-based GHG emissions.
 - 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.
- Much of the potential reduction in GHG emissions from UK-biofuels highlighted above result from the way energy is produced and used in the biofuel conversion plant. The most substantial reductions in emissions result where co-products are used to produce heat and surplus electricity.

Delivering verifiable supplies of low GHG- emitting biofuel feedstocks requires farm-level monitoring and accounting procedures and tools. The farm auditing and GHG calculator tools presented here provide the basis for such monitoring and accounting and can be used by farmers to understand and manage their greenhouse gas emissions. Substantial reductions are possible, particularly through understanding and optimising nitrogen inputs. The outcomes of the two years of farm audits are assessed in more detail below.

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 last two years have demonstrated that the majority of the desired information from farmers is readily available, but the problem has been interpreting this data. A wide variety of different practices are carried out on farms, and this has been easily recorded. However what influences these practices and the GHG implications resulting from them are less certain.

The most influential GHG emissions factor, N fertiliser application rate, is highly variable, for example from 90 to 283kg/ha in wheat. 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 oxidisation of the SOC in these high-organic-matter soils.

Table 1: A selection of farm audit data results

	Wheat		OSR	
	Mean	Standard Deviation	Mean	Standard deviation
Feedstock yield*(t/ha)	8.9	1.24	3.55	0.762
N (kg/ha)	193.7	33.6	191.8	34.7
P(kg/ha)	41.6	n/a	42.5	n/a
K(kg/ha)	36.3	n/a	42.2	n/a
Manure applications	5	n/a	9	n/a
Moisture content (%) after drying	14.7	4.8	8.59	3.121
Moisture removed (%)	1.6	1.6	1.2	1.8
Distance to dryer (km)	2.6	4.6	2.28	2.23

* After drying to storage moisture content

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 CO₂ and N₂O 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* (2007c).

Figure 1 shows the average GHG emissions associated with different agricultural actions for the production of wheat. We have addressed the farm audit data based on the most important factors, namely fertilisers and cultivations.

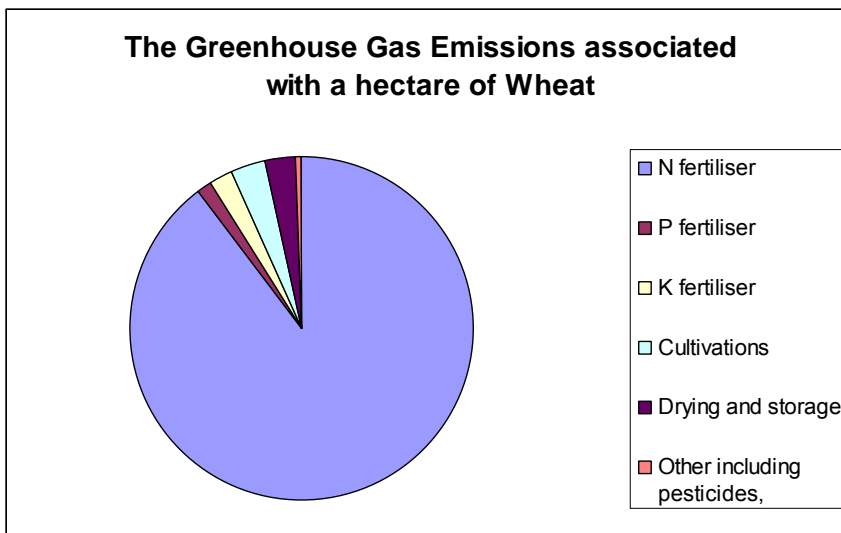


Figure 1: Importance of different factors in determining the emissions associated with wheat (from Mortimer, 2003)

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.

Nitrogen use

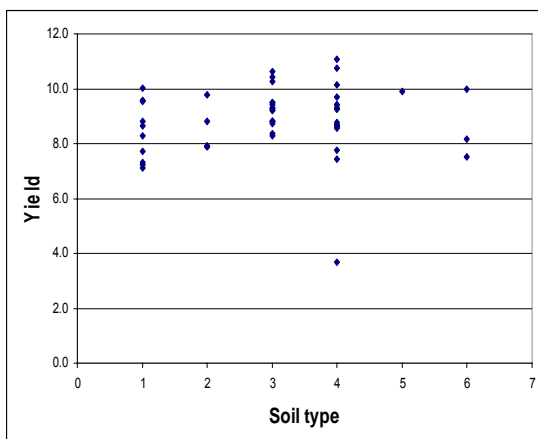


Figure 2: Wheat yield according to soil type

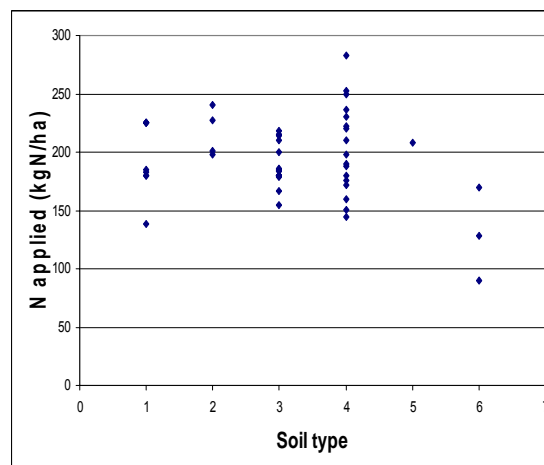


Figure 3: The fertiliser applied per hectare

From the 80 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 2 and 3 show that 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 4 and 5). To demonstrate the importance of N, the Greenhouse Gas Calculator has been used to compare the results between the highest and lowest N users – see Box 1.

Box 1. The importance of N in determining the overall GHG savings of biofuels

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.

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 N₂O released during this process (as well as the CO₂) 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. This is an important area for further research.

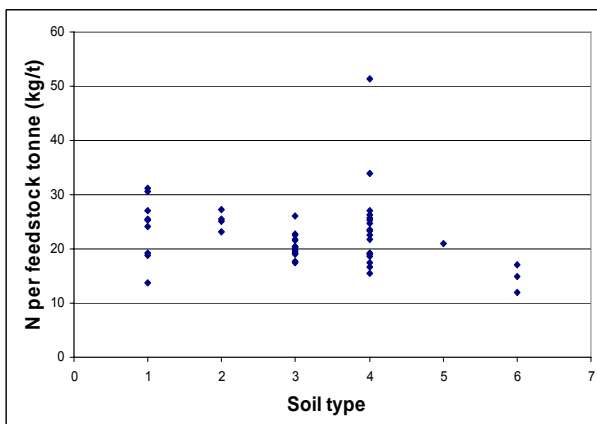


Figure 4: Nitrogen application per feedstock tonne (wheat)

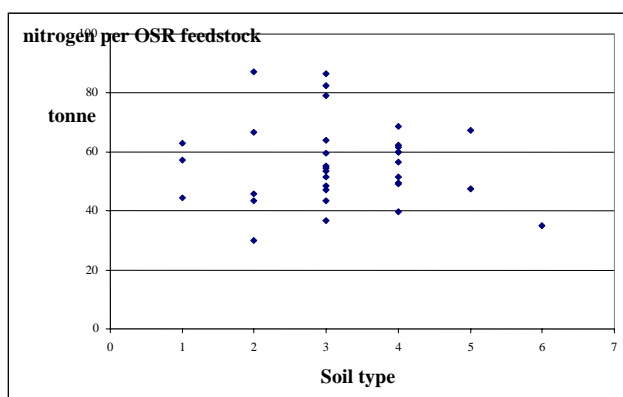


Figure 5: Nitrogen application per feedstock tonne (OSR)

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 last 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.

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.

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 4% and 6% of the farm operations for wheat and OSR respectively. 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 (2007c).

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 CO₂ 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.

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. More detailed research in this area is needed. According to the Mortimer 2003 (see Figure 1), 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.

Conclusions

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 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 more generally. 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.

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