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Development of a carbon footprint protocol for the UK cereals and oilseed sector.

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CONTENTS

1. ABSTRACT

The initial aim of this project is to review existing guidance and methodologies to produce a draft protocol for calculating the carbon footprint of oilseed and cereal crops. The original objectives of the protocol were to encourage both farmer engagement and also help provide farm gate assessments for the supply chain. A second aim was to develop a carbon footprint assessment tool based on this protocol that computer literate growers would find easy to use. A third aim was to test the tool and protocol using real farm case studies to feedback and make any revisions to the protocol to improve accessibility.

Results

Most of the existing greenhouse gas (GHG) product assessment specifications are aimed at retailers and processors. The case studies showed that the initial protocol draft from the review process had some aspects that were of limited relevance or too complicated to enable a grower orientated tool to be developed. For example, obtaining typical inputs and yields from growers for multiple fields and over a number of years to counter the impact of seasonal variability made the approach too demanding. The protocol was revised during tool development, specifically to simplify these data demands.

Conclusions

- The current level of understanding of carbon footprint assessments amongst farmers is likely to be very low. Therefore, to engage farmers, it is important to focus on a simple tool to start with and seek to develop its complexity over time as the farming community's level of knowledge increases;
- A simple carbon footprint assessment protocol applied using a farmer-friendly carbon decision support tool (CDST) is possible. However, a protocol and calculator aimed at growers for competing with existing specifications for reporting retail orientated product carbon footprints would be difficult to implement;
- Even among the most progressive of the case study growers, without an initial element of face to face support the technical data demands of the carbon footprint process would have been difficult, even with the simplified tool;
- Any tool will need supporting with a training programme to help farmers understand how to measure their footprint, what the answer means and how they can seek to reduce their footprint;
- Uptake will be encouraged if areas for improvement can be identified where a focus on carbon efficiency can be aligned with financial performance improvements for the farmer.

2. SUMMARY

2.1. Introduction

2.1.1. Background

The HGCA commissioned this project to assist levy payers in understanding and estimating carbon footprints at the farm gate product level. The demand for this information and evidence for the uptake of measures to reduce farm-level greenhouse gas emissions is growing and will continue to do so. National and international standards do exist for product greenhouse gas assessment. However, these are broad-based specifications for calculating carbon footprints of products and services and are not specifically designed for agricultural products and a degree of flexibility is necessary to allow various methods and data to be used. Also, many carbon calculators and tools exist for farm level GHG reporting. This can result in quite different values being calculated whilst still claiming compliance with the same carbon assessment specifications.

2.1.2. Aims and objectives

The aim of the project was to develop a protocol for the carbon footprint of oilseed and cereal crops and a prototype carbon footprint assessment tool that translates the protocol requirements.

The prototype tool is aimed to be a user-friendly means to provide a robust and consistent carbon footprint assessment. Key scientific and commercial stakeholders in the UK cereals and oilseeds supply chain were consulted as part of the development process to gain industry understanding and acknowledgement of the protocol.

The specific objectives of the project:

1) To review existing protocols and methodologies and assess their suitability for developing a standard carbon footprint assessment protocol for UK cereals and oilseeds up to the farm gate.

2) Based on objective (1), to develop a best practice protocol with guidelines for the calculation of carbon footprints for cereal and oilseed products at the farm gate.

3) To engage with experts and key players in the UK Cereals and Oilseeds supply chain to gain feedback and endorsement of the protocol.

4) To develop a prototype tool to test and refine the standard protocol using appropriate case studies.

5) To develop an eight to twelve page growers' guide to carbon footprint assessment, including advice on mitigation methods and recommendations for best practice data management (e.g. data recording on-farm, minimum data requirements)

2.2. Materials and methods

2.2.1. Review of existing protocols and methodologies (objective 1)

Identifying and selecting existing protocols and methodologies for reviewing

The searching and selection methods used were not exhaustive – as are typical in systematic reviews of clinical or scientific evidence. There is no large body of published standards, protocols and formalised methodologies relating to greenhouse gas assessment of products, especially agricultural products, to warrant this kind of approach.

Pooled project team knowledge base

The team members already have good links to the relatively small research community concerned with GHG assessment of crops as well as awareness of the latest industry developments in research and applied consultancy in this developing field. Therefore the majority of literature and protocols reviewed were found or known of through the project team's experience in the field of carbon footprint assessment and agriculture.

Electronically published resources

In addition to the project team's extensive knowledge base, internet literature searches were conducted using key search terms in a variety of search engines to ensure other English language based protocols and methodologies relating to cereal and oilseed, or more general agricultural related greenhouse gas emissions, were included.

Selection Criteria

A basic set of selection criteria were drawn up to include the most relevant documents for review. In summary, these criteria are given to demonstrate the reasoning behind the kinds of documents that were considered, rather than to develop a detailed and strictly defined process.

Review process

A set of common requirements were defined for product carbon footprint assessments. These were based on the project team's experience and the review of methodological requirements and data needs for a typical product carbon footprint assessment framework with application to crops. Each of the selected protocols, specifications and studies were reviewed and their methodologies and approaches were reported under each of the common requirements.

2.2.2. Draft protocol development (objective 2)

Draft protocol

The review of existing protocols and methodologies informed the development of recommendations for each of the common requirements. These were summarised and discussed in a number of meetings with the project team during the protocol development process. From this process a set of recommendations were made for a draft protocol.

Expert panel review

The draft protocol was split into sections and presented to an expert panel in an electronic survey format for consultation. Experts were selected for their specialist research knowledge and/or involvement with the agricultural industry and Government regarding GHG emissions assessment. The selection was approved by HGCA.

2.2.3. Expert and industry feedback (objective 3)

Expert panel workshop

The results of the consultation were presented to the expert panel and key issues regarding the methodological elements of the protocol also presented and discussed in a workshop format. Key recommendations were noted and added to the development of the final draft of the protocol and tool development.

Industry stakeholder workshop

The tool was demonstrated at the Cereals 2012 event in Boothby Graffoe, Lincolnshire. During the presentation participants were encouraged to submit their own data to the tool in an open demonstration which revealed the key inputs, output, and sensitivities of the tool. The demonstration was accompanied with a presentation of the key issues and sources of emissions from cereal and oilseed crops, the material for which informed the growers guide.

2.2.4. Carbon footprint tool development and case study testing (objective 4)

The case studies for the trial of the tool were selected both via direct contact and intermediaries (e.g. Anglia Farmers) to represent a range of farms in terms of location, scale, ownership, type of farming system (organic and conventional), crop type (barley, wheat and oilseeds), soil type and production system (e.g. including plough based, heavy single pass samba type cultivator, minimum tillage). The farmers selected were also those who were known to be technically competent and progressive as it was felt that these would be more likely to engage in a research and development project, and be more likely to have the data needed to populate the tool.

2.2.5. Growers guide development (objective 5)

The growers guide was developed after the protocol and prototype tool was finalised and the farm case studies had been conducted. The format and structure were aligned with HGCA growers guide requirements whilst fulfilling the necessary project objectives to include mitigation methods and recommendations for best practice data management, such as minimum data requirements.

2.3. Results

2.3.1. Protocol review (objective 1)

None of the protocols and methodologies for estimating carbon footprints for cereal and oilseed crops found as part of this review were designed specifically to enable growers to use.
A very recent British Standards specification for greenhouse gas assessment of horticultural products (including open air field crops) contained requirements aimed more towards downstream assessors, such as buyers and retailers collecting data from growers (e.g. sample size protocols). These kinds of GHG assessment approaches appear to be aimed at larger organisations for regulatory (biomass energy) or voluntary (corporate) supply chain assessments where technical personnel and resources are likely to be available within the organisation to contact growers and support this process.

Allocation

Even within specifications particular to horticultural field crops, a number of methodologies could be employed for attributing growing emissions between crops and straw. The flexibility for interpreting specifications could be one reason for causing different reported emissions for crops that claim conformance to these standards. There are also contrasting views and inconsistencies in definitions and methods outlined by some of the regulatory and key guidance documents with regard to allocating a proportion of the crop emissions to straw.

Uncertainties

Reporting uncertainties is not mandatory in most of the product assessment specifications and few of the other research literature containing GHG assessments report crop specific uncertainty ranges.

Supply chain requirements and/or decision support?

Current specifications, such as PAS2050:2011, may not necessarily require grain processors, food manufacturers or retailers to require individual grower data (secondary proxy data is allowed) so protocols with a different purpose (grower decision support) may not necessarily be guided by these existing standards. The development of a suitable protocol will depend on what is driving the demand for growers to conduct assessments. This is fundamental to understanding the most appropriate approaches to be taken. Initially, the project specified that the protocol and tool would

meet both consistent reporting for supply chain purposes and also be suitably farmer friendly to allow grower decision support. As the project evolved and after the expert panel workshop, the emphasis shifted more towards a simpler protocol to develop a fit-for-purpose truly farmer-friendly carbon calculator for UK cereals and oilseeds. The next section outlines how elements of the proposed protocol were refined in view of this shift of focus.

2.3.2. Protocol development (objective 2)

Elements that were formerly proposed to be excluded that are now included:

Element	Reason
Pesticides production and supply	Completeness - though pesticide production emissions are considered a relatively small contribution to cereal and oilseed crops carbon footprints, since very small quantities of the active substances are used, the indirect impact on yield was thought by some experts to warrant including. Others suggested that pesticides are only insignificant if fertiliser rate is high, and the range of application rates may not be known, so should be included in any tool. Consensus – experts suggested that excluding pesticides would be a departure from other arable foot printing approaches/tools.

Excluded elements that were formerly proposed to be included in the protocol:

Element	Reason
Slow release organic nitrogen (N) (and related nitrous oxide emissions) from intermittent manure or organic inputs that is unavailable within the year of application.	The proposal was to allocate the emissions from delayed N release to crops in a rotation in proportion to the area of these crops in the rotation at the time of application. This was considered to be too complicated for tool input data requirements to account for the different crops in the rotation and their respective area if manure was applied to any of them more than 1 year ago (e.g. the area over which organic inputs is applied is typically limited by the amount available, and thus changes annually). This makes it difficult, in general, to represent the application in rotation prior to the current year unless a complete set of data entry is provided for the whole rotation. It was felt that this effort would discourage the target user-groups at this point in time. Nitrous oxide field emissions attributed to the crop will be based on nitrogen immediately spread before or during crop growth that is readily available to the crop. Recalcitrant or slow release nitrogen is ignored because of the difficulties mentioned above regarding attribution to crops

	within the rotation, and the substantial uncertainties regarding the fate of recalcitrant N in the soil (i.e. whether it is released as N_2O or NO, volatilised, leached, or taken up by the plant). The incorporation of relatively modest effects with very high uncertainties is felt to be detrimental to the purpose of the tool.
Soil carbon sequestration	Although methods exist with which it is possible to quantify the effect of soil management practices on sequestered soil carbon, it should be noted that there are always issues surrounding the permanence of the carbon stock change, the system boundaries, and the implied reference cases. This makes the issues difficult to convey to farmers in a crop calculator and it was felt that the ability to educate users via this mechanism is limited compared to the burden of data entry for quantification.
Land use change emissions	Though the IPCC emission methodology was consistently included or mentioned in most of the key protocols reviewed and was proposed for the protocol it was excluded from the final protocol and tool. It was felt that land use change is not a common concern for UK cereal production since arable land use is typically well established. In general transitions between, say, arable and pasture are temporary and part of established farm management practices (e.g. use of ley crops). These would not be classed as land use changes. Transitions between woodland and arable cropping are better covered in a whole farm assessment since they require assurance of good calibration of the woodland component (adding to the data entry burden and beyond the scope of this project). In addition to these issues many crops are contract managed, thus the farmer may have limited availability of historic land use, tillage or production data within the 20 year period from which any land use change should be counted.
Data quality requirements	These were considered redundant for the tool - since these were only required for conformance reporting – the growers guide provides simple explanations of the secondary data used but not with respect to the quality metrics given in other protocols.
Uncertainty reporting	The prototype tool does not report uncertainty ranges in the final estimates. Informative and engaging reporting of uncertainty would need more resources and would best be included when developing the prototype into a

	mature tool. A qualitative description of uncertainty is given in the growers guide instead.

2.3.3. Expert and industry feedback (objective 3)

The results of the expert and industry feedback are too detailed to summarise within this 10 page summary section and reference to the main section of the report and the appendices is recommended. The expert panel meeting the HGCA and the project team re-evaluated the aims of the project - concluding that the most valuable output would be to provide a tool which offered a farmer decision-support focus, rather than carbon footprints for reporting to supply chains in line with existing standards and specifications.

2.3.4. Carbon footprint tool development and case study feedback (objective 4)

Selected farms

The selected case study farms covered the following counties: Lincolnshire, Humberside, Norfolk, Cambridgeshire, Northamptonshire, Oxfordshire and soil types including peat, clay, silt, loam and sandy brash. The farms ranged in size from 120 hectares (300 acres) to over 1600 hectares (4,000 acres) and included council tenants, owner occupiers and contract farmers. One of the farms was an organic contractor (although they also had some conventional production).

Dividing growing emissions between grain and straw

Most of the case study growers disagreed with the practice of allocating the emissions from crop growing between straw and grain. Basing any allocation on their relative economic value or avoiding allocation through removing emissions associated with other products which straw was considered to substitute was nonsensical for most growers. There were other reasons given by growers as to why straw may be ploughed in or exported off the farm. In the latter case it may not be associated with direct economic value to the grower. Straw may be traded for whatever quantity of manure is available at an adjacent farm but the reason for straw export may be for quick removal in order to prevent the risk that rain may hamper straw removal and delay sowing of following crops. Most case study growers preferred a straightforward approach of applying all the emissions from growing to the grain or oilseed portion of the crop. This would mean that straw at the farm gate is effectively a by-product which has a GHG neutral production.

Organic inputs

Neglecting the contributions of organic nitrogen inputs beyond the application year was considered to be inappropriate by some growers. This also impacts delayed release of nitrous oxide and how this should be shared amongst crops over time (in a rotation). Initial ideas on how this could be approached in a tool interface are presented in Figure 1. Delayed release of nutrients particularly complicates carbon footprints for crops from organic production systems in which the rotation is

divided into fertility building (e.g. clover leys) and fertility exploiting (e.g. cereals) phases. For organic production, a single year approach to assessing inputs is inappropriate as it fails to take account of nutrient depletion in the production of cash crops, and an approach which is able to assess the whole rotation is needed.

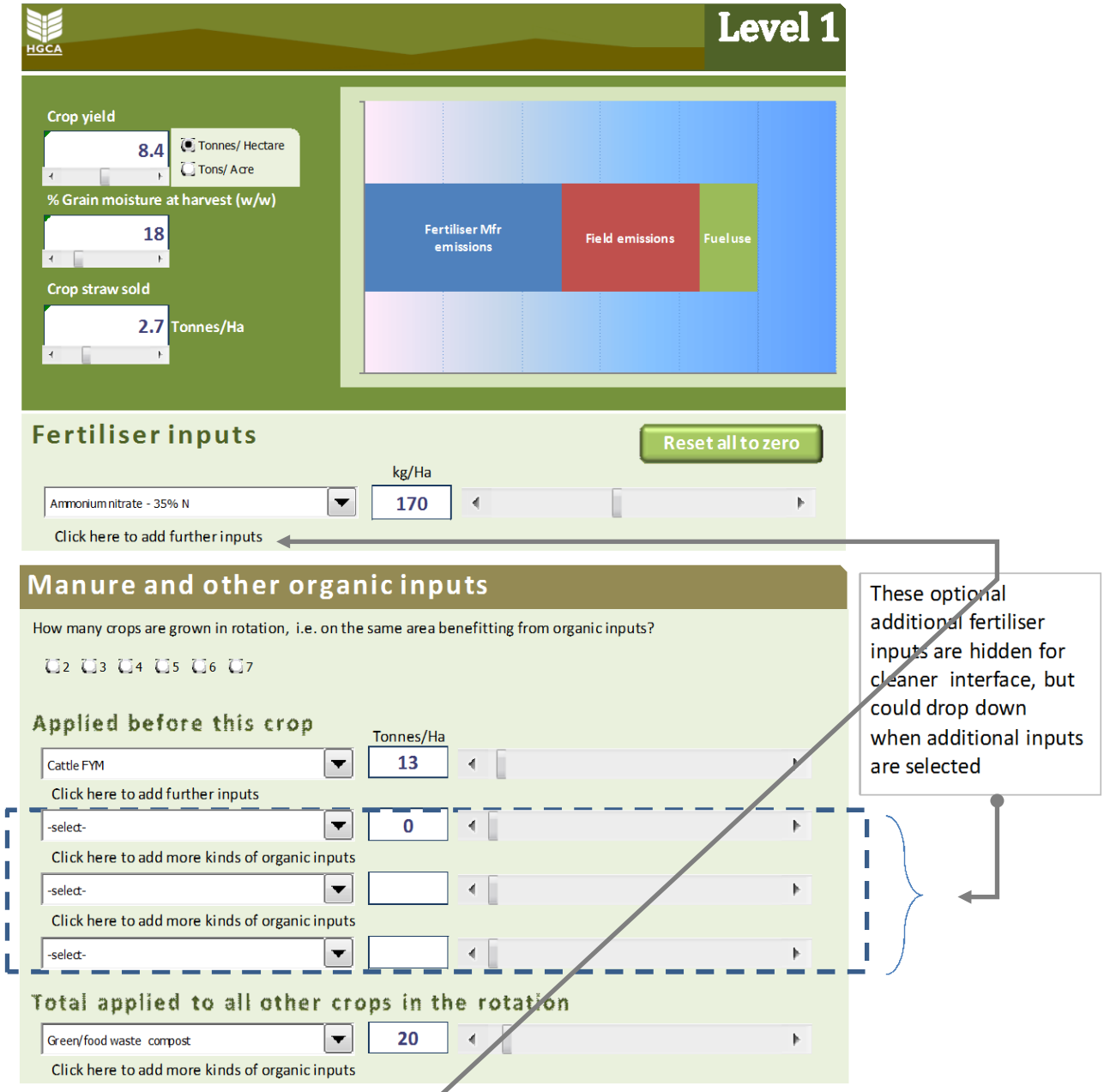

Figure 1. Ideas for user interface for allocating nitrous oxide emissions from the fraction of organic nitrogen sources that is not readily available. Under IPCC methods the same direct nitrous oxide emission factor is applied to 100% of mineral and organic nitrogen added to soils. However N in organic fertilisers that is not readily available to crops may be mineralised beyond the year of application (see main report for discussion on attributing delayed organic nitrogen emissions to crops**)** and could be shared between the crop rotation it benefits**.** This was difficult to achieve in the prototype Excel tool but could be achievable with a professional application for use online.

Due to these complications, and subsequent burden on the grower for data input, delayed nitrogen mineralisation and related GHG emissions were disregarded from the protocol and tool. Integrating these into an easy to use excel based pilot tool was challenging. However this may be possible in

any further development of the tool where rotation is considered and a programming expertise can give greater flexibility to the data entry format.

2.3.5. Growers guide development (objective 5)

The purpose of the growers guide was to describe the key concepts and issues with regard to greenhouse gas emissions from cereal and oilseed crops for growers. It covers the general concepts, concise descriptions of the key issues of soil organic matter, organic farming and uncertainty. It also contains illustrative examples for typical conventionally grown winter wheat, winter oilseed, and malting barley crops and emphasises the concept of "carbon efficiency".

2.4. Discussion/Conclusions and implications

2.4.1. A farmer-friendly product assessment protocol for the supply chain

Growers are under increasing pressure to provide carbon footprints for buyers or for supply chain assessments[1]. The protocol that was developed by this project adopted aspects from existing published standards, some of which are evolving sector specific requirements for horticultural crops. These may also attract the development of specific supplementary requirements for cereals and oilseeds in the near future. However, even the more specific set of requirements adhere to some of the more ambiguous and inconsistent aspects of the parent standard and as such are still open to flexible interpretation.

A 'two tier' approach

Delivering a carbon footprint protocol which has the objectives of being 'farmer friendly' whilst rivalling the more demanding requirements for published product greenhouse gas assessments was a difficult challenge. To resolve this problem a protocol was drafted that allowed either a simple or a more demanding approach. Subsequent expert panel workshop, tool development and testing with case studies emphasised the need for a simple approach for growers. The 'two tier' approach was abandoned in favour of developing a simpler 'farmer-friendly' protocol suitable for a prototype tool. A more detailed protocol would be a medium term goal after a simple tool has generated the required awareness and learning through the grower community. This would be dependent on a successful role out programme.

[1] The original project specification emphasised the supply chain as a key reason for the protocol stating: '*Buyers are also introducing carbon footprint assessment and labelling schemes which require associated farmers to undertake farm-level carbon audits. [HGCA] has received an increasing number of enquiries on carbon footprint assessment as pressure to supply this information grows. To provide levy payers with the best available advice and tools, HGCA wishes to commission a project to develop a standard protocol for farm gate, product-level carbon accounting specific to the UK Cereals and Oilseeds sector. It is likely that this work will be extended to the full supply chain at a later date.*

Compatibility with carbon footprint tools

It was clear from case study testing that a 'farmer-friendly' tool was not compatible with many of the existing formal requirements published for product GHG assessments due to the nature of the data demands but also the different objectives and assessment approach. The published standards are aimed more toward processors and retailers who have the resources to support more demanding data collection and collation and subsequent iterative refinement of estimates. Integrating a protocol through a prototype tool restricts incorporating aspects of existing standards, such as per cent threshold values for including or excluding emissions sources (which will change) or reporting and recording requirements.

Engagement and mitigation

The carbon footprint tool developed in this project was intended to engage with growers to raise their awareness of the contribution of different activities to their crop's carbon footprint. The rationale is that growers would be able to locate and target emission 'hotspots' and make decisions to manage these. An example would be using the tool to understand the GHG impact of changing fertilisers and application strategy.

The tool is developed in a farmer-friendly format. However the case studies showed the need for face to face support to encourage growers to engage with the process and understand where mitigation practices can be focussed.

2.4.2. Implications for cereals and oilseeds product carbon reporting

- A carbon footprint tool developed for successful grower engagement necessitates some kind of active initial support to explain the data required for the technical elements of product carbon footprint assessments. This helps growers interpret the answer produced beyond what can be provided in a grower's guide.

- The level of detail required for a farmer-friendly carbon footprint tool and the application of national emissions reporting methodology to a farm scale assessment limits the sensitivity to management practices to a few key factors that a grower can change. The key relationship farmers need to manage is the type and quantity of nitrogen input used against the resulting crop yield, with other aspects such as diesel use by machinery often of secondary importance.

- Development of a supply chain assessments protocol should be an explicitly separate and distinct process to the development of a (simpler) 'farmer-friendly' tool for grower awareness and engagement to help them identify how to reduce emissions.

- Concerns were raised by growers during case study testing that any minimum performance element e.g. the buyer who said the product they bought had to have a lower footprint than

X kg CO_2eq per tonne (even if unintended) could potentially unfairly discriminate against regions with less favourable soils and climate (and respective differences in inputs and associated yields).

- A key uncertainty in the mitigation argument for encouraging growers to complete carbon footprint assessments is which areas to encourage growers to focus on. Targeting nitrogen efficiency in the farming and food system to improve best practice for recycling nutrients (including composted food waste, AD digestate and biosolids), preventing losses and inhibiting N_2O through fertiliser technology makes good business and environmental sense. However, if carbon footprint assessment is to be used to drive this type of agenda, it is vital to ensure that it does actually do so and is not just an additional burden. The process should complement other crop planning advice and guidance whether driven by agronomic or financial imperatives.

Support process

The project team's experience from conducting the case studies indicates that a standalone tool may be less likely to encourage growers to engage with the process and understand where mitigation practices can be focussed without interactive and complementary support. Case studies showed that once growers were guided through the process and knew which records were required, a process taking over an hour for the first crop assessment took only a few minutes for the final crop assessment. The initial interaction and guidance with the project team member was considered essential to start the whole engagement process, although, this could be delivered to a small group rather than on a one to one basis. Indeed delivering this in small groups is probably preferable as it both reduces the resources needed per farm and leads to the development of friendly rivalry and debate on the best way in which to reduce carbon emissions.

2.4.3. Key conclusions and recommendations

1. A protocol developed for grower engagement should initially be separate to more demanding requirements of existing supply chain mediated reporting requirements[2], which are currently subject to :

    a) Ambiguity caused by an immature consensus of understanding for applying appropriate life cycle product assessment methods;

    b) Models for emissions that are not very sensitive to the impact of specific farm activities;

[2] Or at least if a single document is produced this should have two tiers to satisfy the detail required for these different purposes.

c) A farming community that needs time and support to adapt to this kind of process.

2. Since grower engagement is the main goal of the carbon footprint tool, it is strongly recommended that an active support process needs to be supported alongside the release of the tool to develop a group of committed farmer users. Defra's RDPE supported skills and knowledge framework provides an appropriate vehicle to deliver this, which could also provide much of the resource needed. If this could be coupled to industry sponsorship (by processors, grain customers etc.) for the remaining costs, it would be possible to provide the training at minimal cost to farmers, and have the advantage of attracting their participation through the active support of their customers in setting up the programme.

3. If the rationale for a farmer-friendly carbon footprint protocol is to help growers target emission reductions, more information needs to be developed on how to deliver carbon reductions and how the methods which can be used impact on farm profitability. The case studies clearly demonstrated that even the most progressive farmers did not have a detailed understanding of some notable inputs e.g. fuel use for field operations, but had a desire to learn more about these. Unless there is enough focus on how to reduce their footprint in the roll out programme, it could be argued that farmers are gaining little by way of influencing GHG mitigation which would not be achieved by promoting or adapting existing management processes (e.g. assurance, nutrient plans, improved technical efficiency etc.). Currently, simple farm GHG tools may not have the sensitivity to represent the true impact of management processes where results are functions of basic inputs such as N source, N use and crop yield for a single crop cycle. However, academics and industry are focussing on improving methods for quantified farm level GHG mitigation.

4. If supply chain assessment is also an important requirement, then buyers and downstream stakeholders who require this kind of information from growers should be involved in the roll out consortia to help support the more demanding 'tier 2' requirements. This would require more and longer term support to allow growers to become accustomed to supplying information that is consistent with existing supply chain orientated specifications.

5. A smarter approach for solving the burden of data demands for GHG assessment of crop growing is to integrate carbon foot printing tools seamlessly into farm management software. Investigating whether this is possible with farm management software that is likely to be used widely (now and in the future) by growers or via their agronomists for farm inventory record keeping, financial accounting or assurance schemes could overcome the data demand as the main obstacle to carbon footprinting.