Monitoring the implementation of Farming for a Better Climate and associated greenhouse gas emission reductions – A scoping Study

The Scottish Government

Monitoring the implementation of Farming for a Better Climate and associated greenhouse gas emission reductions – A scoping Study

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The Team

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Contents

List of Figures and Tables

1. Introduction

The Climate Change (Scotland) Act 2009[1] creates the statutory framework for greenhouse gas emission reduction in Scotland by setting an interim 42 per cent reduction target for 2020 and an 80 per cent reduction target for 2050.

Scotland - A Low Carbon Society is a set of publications on climate change, energy and the low carbon economy that describe the benefits and opportunities of building a low carbon Scotland[2]. This document also describes the measures identified to meet the emission reduction targets established by the Climate Change (Scotland) Act 2009, over the period 2010-2022, and the Technical Appendix of the Report on Policies and Proposals[3] details how Scotland will reach its ambition for Agriculture and Related Land Use to reduce emissions in 2022 by 0.9Mt CO_2e compared to 2008.

Emissions of greenhouse gases are within the scope of the UN Framework Convention on Climate Change (UNFCCC) whereas those of ammonia are within the scope of the UN Convention on Long-Range Transboundary Air Pollution (CLTRP). Guidance on the methodologies for calculating greenhouse gas and ammonia emissions is provided in the IPCC Guidelines ('the Guidelines') and the EMEP/EEA Air Pollution Emission Inventory Guidebook ('the Guidebook') respectively. The trend seen within both UNFCCC and CLRTP is for emission limits to be progressively reduced over time. For both greenhouse gas and ammonia emissions, agriculture represents a major source (Scottish Greenhouse Emissions 2009[4] data show that agriculture and related land use accounted for 21% of total GHG emissions, a fall of 1% from 2008 and 27% from 1990).

The Scottish Government (SG) aims to deliver reduction targets partly though a voluntary approach and the Farming for a Better Climate (FFBC) initiative provides a framework for promoting relevant actions by farmers, across five key areas:

- Using energy and fuels efficiently
- Developing renewable energy
- Locking carbon into the soil and vegetation
- Optimising the application of fertiliser and manures
- Optimising livestock management and storage of waste

In order to assess progress toward targets, the SG needs to be able to monitor the implementation of greenhouse gas (GHG) mitigation measures (MMs) and thus anticipate the extent to which emissions are being reduced. This study focuses on monitoring the implementation of FFBC and associated greenhouse gas (GHG) emission reductions. This reflects the need to provide

1 http://www.scotland.gov.uk/Topics/Environment/climatechange/scotlands-action/climatechangeact
2 Low Carbon Scotland: Meeting the Emissions Reduction Targets 2010-2022
3 http://www.scotland.gov.uk/Publications/2011/03/10163857/0
4 http://www.scotland.gov.uk/Publications/2011/09/05094939/0 (accessed September 2011)

evidence on programme impacts, both to inform policy development and to quantify emission reductions which are not currently captured by the UK GHG Inventory. It is important to note that this is a scoping study and decisions on implementation of the findings will be made by the SG at a later stage.

Emissions are estimated by multiplying activity data with emission factors. Compiling the national inventory therefore comprises two main steps: (i) obtaining national activity data and (ii) choosing emission factors (either default or country specific emission factors). At present, the inventory does not account directly for many of the MMs farmers can adopt and therefore is not suitable for monitoring and evaluating Farming for a Better Climate. This scoping report is designed to redress the limitations of the headline inventory figures in order to understand the extent to which management practices are changing in line with FFBC recommended actions and their likely impact on GHG emissions.

1.1 Data needs and collection

The data needs for calculating GHG emissions (CO_2, CH_4, and N_2O emissions) relate to the level of uptake of GHG reducing activities and information on the relevant emissions impact e.g. emissions factors. These needs are relatively large, especially for large emissions sources where there is a consequent need for more accurate data as the impact of incorrect estimates would be proportionately greater. Data are not always available from existing sources and emissions from agriculture are complicated by the large number of sources and the variability between them (in terms of management and natural variability). Much data is already collected to estimate emissions from agriculture in aggregate and there is also a multitude of other data being collected for other policy purposes. Existing data that can be used to describe the activities that lead to changes in agricultural emissions ranges from the June Census, the Farm Accounts Survey, IACS, and the various land cover and soil maps.

The MMs recommended as part of the FFBC will be implemented across a broad range of farm types with different characteristics who are subject to many factors that affect management options available and their uptake. This suggests that a large amount of data will be needed from many sources.

Activity data

A recent EU project was tasked with creating a framework of data collection from farmers and other sources to produce agri-environment indicators for policy makers. The DireDate[5] project, undertaken for Eurostat, has provisionally suggested that based on experiences in various countries, farm structure surveys should be carried out every five years for collecting

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[5] Direct and indirect data needs linked to farms for Agri-Environmental Indicators (AEI). DireDate is a project that Eurostat, the statistical service of European Commission, set up to get recommendations for setting-up a sustainable data collection system, based on best practices, for developing the agri-environmental indicators of the EU. The aim of DireDate was "*To create a framework for setting up a sustainable system for collecting a set of data from farmers and other sources that will serve primarily European and national statisticians for creating the agreed 28 agri-environmental indicators and thus serve policy makers, but as well agricultural and environmental researchers, observers of climate change and other environmental issues linked to agriculture*."

information about housing systems, manure storage systems and manure application techniques i.e. data on activities. DireDate distinguishes the main NH_3, CH_4 and N_2O emissions sources and qualifies data requirements into two categories, "optimum" and "minimum". It highlights activity data that must be collected, because without these data, proper inventory reporting is not possible. Where only the minimum requirement is met, the effect of mitigation measures will not be reflected in the inventory and their cost effectiveness cannot be assessed. DireDate also highlighted activity data that should be collected to more accurately estimate inventories which offer more possibilities for country-specific and cost-effective mitigation measures and enable the assessment of environmental impacts of farm management practices.

For FFBC, activity data that capture uptake of the mitigation measure are required, and therefore will more closely relate to the optimum requirements in DireDate. For example, the minimum activity data requirement for slurry application is the application technology and application to arable or grassland, whereas the optimum requirement is for data about the timing and amount of application and whether or not slurry is incorporated after application to be collected. The latter are more likely to enable the assessment of mitigation measures, including the ones under FFBC.

GHG Impact

Whilst activity data alone are sufficient to monitor uptake of FFBC measures, sufficiently detailed emission factors are required to assess the GHG impact of this uptake. Sometimes the emission factors used in the Inventory will be sufficient, if, for example, the mitigation measure directly affects the rate of application of fertiliser and this change in fertiliser use can be quantified. For others, new emission factors would be required, for example carbon loss from drained vs. un-drained moorland.

Soil carbon is a significant issue in Scotland where the cool, moist climate has encouraged the retention of decomposed organic materials and over time the creation of important global reserves of soil carbon[6]. The importance of Scotland's soil carbon is illustrated by the fact that if 1% of the carbon therein was lost in a year, Scotland's total emissions would treble. Soil carbon can be lost in the course of cultivation of agricultural land and soil management should therefore encourage the accumulation of soil organic matter to retain the carbon as well as maintain soil health and fertility.

A number of the MMs are focussed on the preservation and enhancement of soil organic content and soil carbon. However, there are some crucial gaps in knowledge in the measurement of soil organic carbon content and it is not known whether total organic carbon is changing as most studies have not considered the whole soil profile. It is also accepted that there are knowledge gaps in terms of the effects of land use change on soil organic matter storage and future changes are difficult to predict.

Whilst it is generally possible to collect information in order to estimate reductions in GHG emissions, it is much more difficult to attribute such

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[6] The *State of Scotland's Soil*, Scottish Government 2011

changes to specific drivers. This issue of attribution of GHG impacts will be discussed throughout this report.

1.2 Terms of reference

There are two key requirements:

(i) A suitable suite of indicators of change which can be used to quantify impacts. The selection of indicators needs to be informed by an understanding of the science of GHG emissions and international conventions on calculating GHG impacts but also by the practicality of data capture.

(ii) An appropriate and proportionate approach to data collection which does not duplicate existing reporting or represent a significant burden for farmers and land managers. The data should be sufficiently robust (fit for purpose) but importantly discern the extent to which change is ‘additional’ (i.e. more than would be done in the absence of the programme) and associated directly with FFBC actions.

1.3 Structure of the report

Section 2 describes the method utilised to suggest a set of indicators relating to the implementation of the FFBC programme. It also describes the format of a set of fact sheets that describe different facets of the 26 MMs assessed such as the changes in farm input and outputs, the GHG impacts, and the data needs to describe the impacts. These fact sheets are contained within the appendix following section 3 which discusses the issues raised in the analysis.

2. Method

The specific requirements of the study suggested a method based upon:

(a) Identifying pathways to GHG emissions reductions, linking specific actions to GHG emissions reductions.

(b) Identifying indicators capturing key elements of the logic chain from inputs (e.g. uptake of specific measures or actions) to outcomes.

(c) Assessing data requirements for the indicators and how data might be captured (availability and reporting frequency), including identification of data gaps and solutions.

These tasks are largely sequential and the method addresses them in turn, with some overlap. Key principles underpinning the approach taken include:

(i) Mapping of pathways should be comprehensive and while focused on GHG mitigation, should also identify external drivers e.g. reduced stock numbers and capture secondary and incidental impacts e.g. water quality benefits.

(ii) Indicators should be capable of clear definition, including the basis for calculation, and should be practical in terms of availability of data capture.

(iii) Data capture should aim to utilise existing surveys and recording requirements where possible and recognise the need to aggregate up to a country population.

The method is simple and was designed to utilise the wide ranging expertise available to the project. It ensures that required science, farming system, data, and GHG inventory expertise are corralled together to provide a clear response to the objectives.

2.1 The Building Block Approach

The method builds upon that utilised in the DireDate project, which used a "building block" approach, whereby data requirements of indicators are broken down to their simplest measurable components and given a visual impact, with the colours indicating which category the data belongs to. The blocks can be used many times for different functions.

Two types of building blocks were distinguished, (i) those for primary activity data and (ii) those for coefficients (defined as "factors which cannot be derived directly from statistical surveys, and therefore have to be derived/assessed indirectly e.g. from scientific reports and papers or from simulation modelling). Examples of coefficients are excretion factors and emission factors.

In DireDate, the building blocks are grouped into the following categories: Inputs (nutrients, pesticides, water, and energy), Land cover, Crop production, Livestock production, management (Livestock and Farm) and soil and water quality.

Inputs	**Land cover**	**Crop production**	**Livestock production**	**Livestock and farm management**	**Soil and water quality**

Figure 1 below shows a number of these categories of building blocks for the "GHG emissions from agriculture" indicator.

Figure 1: Example of DireDate building blocks for GHG emissions from agriculture

MANAGEMENT	**INPUTS**	**SOIL AND WATER QUALITY**	**LAND USE/NATURE / CLIMATE**	**CROP PRODUCTION**
Housing	Feed intake	C excretion	Climate	Crop residue
Manure storage: duration/capacity	Mineral N fertiliser use per farm	N excretion	Crop area	
Manure storage: type	N Fertiliser type	Livestock number by species		
Manure application technique	N in imported manure			
Grazing days	N in exported manure			
Manure treatment	N in supplement added to AD			
Time of manure application	Manure N application			

In this project, the building blocks are used to indicate where there are similarities and differences in data needs between the MMs and also the amount of data required. It is expected that some of the MMs will be directly based on one or a limited number of activity data and coefficients (e.g. the use of nitrogen fertiliser). However, others might have to be calculated from large sets of activity data and coefficients. It is also apparent that a number of new building blocks are required to fully describe the MMs. Where new blocks have been used, they are marked as such within the fact sheets.

The building blocks will also highlight where there is an overlap in the need for data in some the MMs, especially those related to fertiliser and manure use. This will give an indication of the potential for harmonised data collection.

DireDate incorporated a number of other principles that are relevant to this project. These include:

- Primary source principle, i.e., data collected directly at source, at the farm level, is likely to have greater accuracy than data derived from indirect sources. This principle has clear relevance to FFBC in the area of programme attribution to higher level indicators of GHG emissions reductions
- Effectiveness and efficiency principles, i.e., collect the data only the number of times that is necessary to provide a sensible impact assessment. This principle relates to minimising the burden upon farmers and that collection needs to reflect realistic timescales over which the MMs might be expected to impact on emissions.
- Other principles relate to prioritisation of activities to create indicators and who should undertake data collection. Prioritisation might reflect those MMs with the greatest potential for GHG reduction and are linked directly to the themes in the FFBC programme

2.2 Mitigation method fact sheets

The mitigation methods are described in a series of fact sheets, which follow a common format. This covers the background and context, the logic chain from action to impact and MM characterisation and measurement. The narrative includes acknowledgment of minor GHG impacts and inventory issues as well as some of the factors that make it difficult to attribute implementation to FFBC.

It is important to note that the MMs and their impacts are presented in the fact sheets in generic terms. We recognise that, in practice, actions are implemented within a local context or set of conditions and subject to natural and management variability which this document cannot capture. As such, the impacts will also be variable and complex.

For each of the MMs the fact sheet sets out the following information:

- Baseline – this describes the management practice without the MM
- MM application – how the MM is applied at the farm level
- GHG Impact – how the MM leads to GHG impacts (major)
- Changes in farm input and outputs – for those MMs that result in changes in inputs and outputs. This includes potential impacts on production that could lead to emissions export. It is also true that productivity enhancements could offset such emissions export
- Measurement – ideally how the MM would be measured and how often
- Building blocks – states which building blocks are required to measure the MM uptake and resultant major GHG impact

- Data requirements – relates the building blocks to specific data requirements, including units
- Existing data sources – existing data sources that may be able to fulfil the data requirements
- Potential new data sources – considers the difference between data requirements and existing data, identifies gaps and suggests new data sources to close the gaps
- Conclusions – uses a traffic light approach to gauge the sufficiency of existing data to indicate MM uptake and GHG impact.

For each mitigation method a logic chain flow diagram from the baseline (current practice without the MM) to the actual GHG impact is presented. For the GHG impacts we have included both direct and indirect impacts shown as major and minor impacts, with the former in bold. Direct impacts arise from the operation within the farm gate, whereas indirect impacts are generally those beyond the farm gate. For example, reductions in energy use on farm resulting from a decrease in the use of farm machinery are direct, whereas the reduction in energy use resulting from a decrease in the manufacture of fertiliser supplied to the farm is indirect.

We define the **major** GHG impact as the largest magnitude of effect that implementation of a MM will have in terms of GHG emissions. Minor GHG impacts are defined as any others that are abated (or indeed increased) as a result of the measure. However, it has proved difficult for a number of MMs to definitively identify the major impact due to uncertainty in emissions factors. There are also a range of characteristics that make impacts variable e.g. farm type, qualifying all changes that take place etc. Thus, for a number of MMs, our assessment of the major GHG impact is tentative.

The measurement, building blocks, data requirements and data sources are classified as being either ‘Primary’ or ‘Secondary’. Primary data are defined as those required to monitor the *uptake* of a MM, irrespective of the GHG impact. Secondary data are defined as those required to monitor or estimate the *major GHG impact* as a result of uptake of the MM. These could be considered analogous to ‘result’ and ‘impact’ indicators in the Common Monitoring and Evaluation Framework of the RDP (2007-13).

The measurement section provides information on ideally how often the measurement of the MM uptake should be made, based on expected rate of uptake and natural fluctuations. In general, MMs that relate to changes in cropping, fertiliser application etc. that could be relatively easily implemented and are subject to annual or seasonal variations should be measured on an annual basis. More permanent changes such as significant changes in management or land use should be measured less often (e.g. every 5 years), since they will be taken up less rapidly. Other changes, for example adopting good irrigation practices, may be intermediate between the two.

In the conclusion section, the ability of the existing data sources to provide sufficient information to monitor (i) uptake of the measure and (ii) the major GHG abatement are classified into **Green**, **Amber** or **Red**, where **Green** means that the available data are wholly sufficient; **Amber**, that the available data go some way towards providing all of the necessary information; and **Red**, that the available data are not thought to be at all sufficient.

Also included in the fact sheets are potential impacts on other ecosystem services. These are characterised using the representation as used in the National Ecosystem Assessment.

For all the following MMs we use the description of ecosystem services from the National Ecosystem Assessment (http://uknea.unep-wcmc.org/Home/tabid/38/Default.aspx). It omits biodiversity which is seen as fundamental to the provision of all other services. Where MMs have an impact on biodiversity, this is mentioned in the narrative bullets before each.

Regulating services:
The benefits obtained from the regulation of ecosystem processes.

For example,
- climate regulation
- hazard regulation
- noise regulation
- pollination
- disease and pest regulation
- regulation of water, air and soil quality

Supporting services:
Ecosystem services that are necessary for the production of all other ecosystem services.

For example,
- soil formation
- nutrient cycling
- water cycling
- primary production

Cultural services:
The non-material benefits people obtain from ecosystems.

For example, through
- spiritual or religious enrichment
- cultural heritage
- recreation and tourism
- aesthetic experience

The MMs incorporated in the FFBC programme are, in general, designed to optimise production i.e. reduce GHG emissions per unit of production. However, it is important to note that a small number of the MMs could have negative impacts on food production and simply lead to GHG emissions being exported elsewhere. These include: MM4: Fuel production biomass (but this would still produce an income); MM5: Restore soils with high organic matter content; MM11: Crop rotations (particularly including grass); and MM13: Creating margins. MMs closely related to Environmental Stewardship options should not represent any significant change in farm income. Others, such as MMs 23-26 that target livestock emissions, would very much be expected to improve productivity and potentially expand food production.

For those measures where there may be a potential negative effect on production, it should be recognised this will vary for each farm business. For example, measures such as tree planting may complement a farm business where done on marginal land or used to provide shelter for stock and the measures which target soil erosion may improve quality of soils and therefore productivity in some cases. Fundamentally, we would only expect a farm to take forward measures where they make sense in terms of the business objectives of the farm.

3. Results

3.1 MMs and data gaps

For each of the MMs, an assessment of the sufficiency of existing data sets to describe their uptake and GHG impact was undertaken using a traffic light system, based on the project team's judgement. However, it should be noted that the "lights" do not account for the attribution of uptake to the FFBC programme *per se*, as opposed to other drivers. This would require another layer of evidence dealing specifically with the effectiveness of FFBC in changing behaviours. Table 1 presents a summary of the data sufficiency traffic lights.

FFBC theme	Mitigation method	Uptake	GHG Impact
Energy & fuel use	MM1 Energy Audit	Amber	NA
	MM2 Implementation of Energy Audit	Red	Amber
Renewables development	MM3 Energy generation	Amber	Amber
	MM4 Fuel production	Green	Amber
Locking carbon into soils and vegetation	MM5 Retain and conserve high organic soils	Amber	NA*
	MM6 Restore high organic soils	Green	Amber
	MM7 Manage existing woodland and create new	Green	Green
	MM8 Reduced till on suitable land	Amber	Red
	MM9 Incorporating crop residues	Amber	Red
	MM10 Growing cover crops	Green	Red
	MM11 Crop rotations	Amber	Red
	MM12 Good irrigation practices	Amber	Red
	MM13 Creating margins	Green	Amber
Fertiliser and manure optimisation	MM14 Apply at recommended rates	Green	Amber
	MM15 Apply at recommended times	Green	Amber
	MM16 Measure nutrient value of manure and slurry	Amber	Amber
	MM17 Separate slurry and fertiliser applications	Amber	Amber
	MM18 Low N varieties/ efficient N fix	Amber	Amber
	MM19 Composts/straw based manures	Green	Amber
	MM20 Methods of slurry application	Green	Amber
Livestock management and waste storage optimisation	MM21 Cover stored slurry and manure	Amber	Amber
	MM22 Aerate stored slurry and manure	Red	Red
	MM23 Draw up and regularly review animal health plans	Green	Amber
	MM24 Promote efficiency with regards to breeding	Red	Red
	MM25 Promote efficiency of food conversion	Red	Red
	MM26 Feed balance	Red	Red

Table 1: Summary of sufficiency of current data

Some of the principle factors behind the traffic light colours are briefly presented below. A fuller explanation can be found in the relevant fact sheets in the Appendix.

Energy and fuel use: The amber score for MM1 is due to uncertainty in being able to capture all the audits that occur on farms (GHG impact is blank since none will occur for an audit). Uptake for MM2 is red since there is no known data source describing the implementation of audit recommendations. National data on energy consumption by sector and fuel type is available but it is difficult to relate changes to energy use on farm.

Renewables development: MM3 uptake can be captured via Rural Priorities Scheme options data but other installations outside this scheme will not be captured. GHG impact would ideally use farm level data.

In terms of biomass production (MM4) IACS data and June Survey data could capture uptake. Carbon emission factors from the current LULUCF inventory could be used to estimate changes in carbon loss under different land uses if changes were major (e.g. from permanent grassland or woodland to Miscanthus).

Locking carbon into soil and vegetation: The uptake of MMs in this group could be identified via reference to RDP data as well as a regular farm practice survey such as Survey on Agricultural Production Methods (SAPM). As the title of this group of MMs suggests, soil carbon is the target. However, as mentioned earlier, there are a number of significant gaps in knowledge that make measurement of soil carbon changes particularly difficult and thus most of the GHG impacts for this group are red.

Fertiliser and manure optimisation: This group of MMs is generally better described by existing data sets. Green cells for uptake relate to datasets such as the appropriate Rural Priorities Option within the Rural Development Programme and the British Survey of Fertiliser Practice. A number of the amber cells for uptake relate to the grant scheme not capturing all activity.

All the GHG impact cells are amber. This relates to emissions factors with large degrees of error (these are being addressed by the greenhouse gas platform projects discussed in more detail below).

Livestock management and waste storage optimisation: Of note is the preponderance of amber in the GHG impact column and the red lights in the livestock management MMs. This relates to a lack of data in the public domain (e.g. aeration of slurry tanks, breeding efficiency).

Table 2 summarises which building blocks are used for each of the MMs. The horizontal shaded lines show the blocks that are used in 5 or more MMs and the vertically shaded lines those MMs that use 5 or more building blocks. This shows that 12 of the building blocks are used in 5 or more MMs but 17 of the 26 MMs use 5 or more building blocks. Two of the building blocks used in more than 5 MMs are Direct Energy Use in Agriculture and Direct Energy Use by Activity which relate to a relatively minor part of total emissions from agriculture. On average, each building block is used just over two times. Those MMs highlighted in red are those with at least one of the uptake and GHG impact traffic lights of that colour. This highlights the difficulties associated with the diffuse nature of the data requirements in the assessment of the impact of the MMs.

	MM1 Energy Audit	MM2 Implementation of Energy Audit	MM3 Energy generation	MM4 Fuel production	MM5 Retain and conserve high organic s	MM6 Restore high organic matter soils	MM7 Manage/create woodland	MM8 Reduced till on suitable land	MM9 Incorporating crop residues	MM10 Growing cover crops	MM11 Crop rotations	MM12 Good irrigation practices	MM13 Creating margins	MM14 Apply at recommended rates	MM15 Apply at recommended times	MM16 Nutrient value of manure and slurr	MM17 Separate slurry and fertiliser	MM18 Low N varieties/ efficient N fix	MM19 Composts and straw based manur	MM20 Methods of slurry application	MM21 Cover stored slurry and manure	MM22 Aerate stored slurry and manure	MM23 Animal health plans	MM24 Promote breeding efficiency	MM25 Food conversion efficiency	MM26 Feed balance
Number of farm energy audits	✓	✓																								
Number of farms adopting energy audit recs		✓																								
Direct energy use in agriculture		✓	✓	✓				✓	✓	✓		✓								✓						
Direct energy use by activity				✓				✓	✓	✓		✓								✓						
Indirect energy use in agriculture																			✓							
Mineral N fertiliser use per farm														✓	✓	✓		✓								
Amount of N applied per crop														✓	✓	✓	✓	✓								
Manure N fertiliser use per farm														✓	✓	✓										
Biological N fixation																		✓								
Organic fertiliser type																			✓							
N in imported manure																			✓							
N in imported compost																			✓							
N in imported slurry																			✓							
Feed intake																									✓	✓
Nutrient composition of food																									✓	✓
Crop area by crop type				✓					✓					✓	✓	✓	✓	✓								
Land cover by type					✓	✓	✓																			
Land use change by type				✓		✓	✓																			
C sequestration: woodland							✓																			
Total arable area											✓		✓					✓								
Total grassland area																		✓								
Landscape: water buffer zones													✓													
Landscape: other uncultivated margins													✓													
Renewable energy production: agriculture			✓																							
Crop yield by crop type			✓																							
Area of managed woodland							✓																			
Area with spring crops										✓																
Area with catch crops										✓																
Arable area with grass in rotation											✓															
Crop N uptake																	✓									
Percentage of clover in grass																		✓								
Livestock number by species			✓																				✓	✓	✓	✓
Meat produciton by species			✓																				✓	✓	✓	✓
Egg production by species			✓																				✓	✓	✓	✓
Milk production by species			✓																				✓	✓	✓	✓
Offspring production by species																							✓	✓		
Barren females by species																							✓	✓		
Animal health plans																							✓			
Quality of breeding stock																								✓		
Diet plans																										✓
Farm typology	✓	✓							✓									✓	✓					✓		
Farm area												✓								✓						
Total number of farms	✓															✓	✓									
Area reduced soil tillage								✓																		
Area zero soil tillage								✓																		
Fertilised area per farm														✓	✓	✓	✓	✓	✓							
Straw management									✓																	
Number of farms testing manure/ slurry																✓										
Time of manure N application															✓		✓									
Time of mineral N application (new)															✓		✓									
Manure application technique																				✓						
Irrigated area												✓														
Type of irrigation installed												✓														
Manure stored in covered tanks																					✓					
Manure stored in lagoons																					✓					
Manure stored in manure heaps																					✓					
Manure stored in underfloor pits																					✓					
Slurry stored in un-aerated store (new)																						✓				
Slurry stored in aerated store (new)																						✓				
Ammonium-N EF from manure by storage type																					✓					
Ammonium-N EF from slurry by storage type																					✓	✓				
Soil properties: organic carbon content					✓	✓																				
Soil properties: carbon loss				✓		✓				✓	✓															
Soil properties: suitable reduced till								✓																		
Soil properties: N2O loss (new)													✓	✓	✓	✓										

Table 2: Building blocks used by MM

Each of the MM fact sheets in the Appendix include a short description of potential new data sources required to fill identified data gaps. This information has been used to better illustrate the type of data gaps that need to be filled to better evaluate FFBC. It differentiates between activity data related to a farm practice survey and emissions data. The gaps are indicated ticks in Table 3.

	Activity data	**Emissions data**	
		N_20 and CH_4	**Soil carbon**
MM1 Carry Out an energy audit	☐		
MM2 Implementation of energy audit	☐		
MM3 Energy generation	☐		
MM4 Fuel production			☐
MM5 Retain and conserve high organic soils	☐		
MM6 Restore high organic soils			☐
MM7 Manage and create woodland			
MM8 Reduced till on suitable land	☐		☐
MM9 Incorporate crop residue	☐		☐
MM10 Growing cover crops			☐
MM11 Crop rotations	☐		☐
MM12 Good irrigation practice	☐		☐
MM13 Creating margins			☐
MM14 N rates		☐	
MM15 N timing		☐	
MM16 Nutrient value of manure and slurry	☐	☐	
MM17 Separate slurry and manure application	☐	☐	
MM18 Low N varieties	☐	☐	
MM19 Composts/straw based manures			
MM20 Slurry application			
MM21 Cover slurry and manure	☐		
MM22 Aerate slurry and manure	☐		
MM23 Animal health plans			
MM24 Breeding efficiency	☐		
MM25 Food conversion efficiency	☐		
MM26 Feed balance	☐		

Table 3: Data gaps by broad type

The activity data could be gathered via a dedicated farm practice survey or by additional questions to existing surveys. Many of the missing or not sufficiently accurate N_2O emission factors could be provided by the GHG Platform projects. The livestock related MMs are not ticked for the CH4 emission factors here since they relate to production efficiency in terms of head of livestock needed to achieve a certain level of production, However, the GHG Platform projects will be looking at breed and feed related emissions factors that would be of use here.

3.2 Attribution of MMs to the FFBC Programme

It is clear from the analysis that there is a gap between, on the one hand, the datasets and coefficients that can describe changes in emissions from agriculture in general or those resulting from changes in farm management practices in particular, and on the other hand, the attribution of those changes to specific drivers such as the FFBC programme. At the national scale this reflects the need to improve data gathering to better describe the processes by which the agriculture GHG inventory is changing over time. In terms of FFBC, this reflects the real difficulties in attributing any changes to a specific driver.

Attribution to the FFBC programme is difficult given the other drivers of change in farm management practices. It may be possible to estimate the contribution of the programme to overall reductions in GHG emissions from agriculture via a survey of participants as well as farmers who have not been engaged. This is further complicated insofar as farmers that have had no direct contact with FFBC could have been influenced by the programme indirectly via the farming community or the various media pathways.

3.3 Filling the gaps

There are three aspects to improving the capacity to monitor the impact of the FFBC programme:

a) farm practice activity;

b) emissions factors,

c) attribution of emissions changes to FFBC.

Allied to this is the need to have a **baseline** from which to evaluate FFBC progress. In the case of FFBC this would be the GHG emissions in the absence of the programme. This would be expected to change over time since farmers would continue to change practices due to a host of other drivers. Similar baselines were used in the marginal abatement cost curves for agriculture[7] that forecast "business as usual" emissions. The Food and Agricultural Policy Research Institute (FAPRI) has also estimated updated baselines for Scotland. The bases for these baselines would need to be assessed before concluding whether they are sufficient for FFBC evaluation e.g. what assumptions are made with respect to other factors that would affect emissions from agriculture.

Current and future measurement of emissions from agriculture will include the effect of the FFBC programme. To separate the impact it is necessary to quantify the difference between current and future emissions and the baseline

[7]Review and update of UK marginal abatement cost curves for agriculture, Committee on Climate Change, 2010

that would theoretically include the programme impact. Depending upon the assumptions within the baseline, it will likely be very difficult to attribute emissions changes specifically to MM implementation due to FFBC programme activity.

3.3.1 Activity: Farm practice survey

The first aspect expresses the need for a more regular farm practice survey as recommended by the DireDate project. The survey could cover a multitude of requirements from different policy areas to ensure value for money and limit the burden on farmers.

For most of these data, the additional effort for collecting them is small and the additional benefit is large. The DireDate project recommended that farm structure surveys should be carried out every five years for collecting information about housing systems, manure storage systems and manure application techniques to inform environmental indicators. The same suggestion is made here for FFBC. Much of the data collected as part of the first SAPM survey in Scotland (2010) is relevant to the monitoring of the uptake of FFBC mitigation measures, therefore a regular survey of farm production methods or farm practice (every 2-3 years to coincide with EC Farm Structure Survey requirements) is recommended in order to generate a time series of data. Additional questions relevant to FFBC MMs could be added as required. Table 3 provides an indication of what activity data might be covered by such a survey.

3.3.2 Emissions Factors: GHG Inventory improvements

The second relates to work already underway to improve the UK Agricultural GHG Inventory data which is due to report at various stages over the next 2-4 years. These projects (which apply to N_2O and CH_4 emissions, but not CO_2 from soils and energy) should allow the effect of specific MMs to be assessed more accurately both spatially and temporally. Part of this work is to improve the accuracy and specificity of emission factors to enable effects of mitigation measures to be reflected in the Inventory. Whilst outputs from these projects are not imminent, if the necessary activity data to enable the uptake of FFBC MMs were to be collected at baseline, improved emission factors could be applied retrospectively to these activity data to estimate GHG emissions from agricultural sources in Scotland at baseline.

Of particular note are a group of concurrent projects

AC0112: Producing inventories of ammonia and greenhouse gasses from UK agriculture for international reporting requirements

AC0114: GHG platform - Data management

AC0115: GHG Platform - Methane Emissions Factors

AC0116: GHG Platform - Nitrous Oxide Emissions Factors

It is recognised that the current National Inventory of GHG emissions from UK agriculture does not use a sufficiently detailed methodology to be able to measure, report and verify reductions achieved by government policy and voluntary industry actions. The current approach is based largely on the 'Tier 1' use of generic UK assumptions about farm practice and default emission factors taken from the IPCC Guidelines for National Inventories (Intergovernmental Panel on Climate Change, 1996 Guidelines for National Inventories and 2000 Good Practice Guidance). These projects are looking to develop more detailed methods (IPCC 'Tier 2' or 'Tier 3' for all major sources) with UK-specific emission factors. The latter would be based upon detailed agricultural data that map regional and sector differences in farm practice and, importantly for this project, that can track the adoption of mitigation methods by the industry. The planning and prioritisation of mitigation also requires improved understanding and accuracy of emission factors, in order to reduce the uncertainty in emission projections. This would aid the targeting of specific activities and increase our confidence that targets will be met.

The GHG Platform project (AC0114) is being led by ADAS and is expected to report on the following objectives that are of relevance to the monitoring of the FFBC programme:

- Country specific emissions factors approved for reporting: A revised set of inventory emission factors for nitrous oxide and methane derived from a synthesis of both published and unpublished literature and experimental data from the UK, supported by model based interpolation of measured data to representative geo-climate zones.
- Better disaggregation of national emissions along agricultural sector and product lines and increased spatial and temporal resolutions. This includes a disaggregation of the UK Agricultural Survey and farm practice data according to a typology of representative farm systems (conventional, organic, upland, lowland, dairy, arable etc), soils and climate zones.
- Integrated accounting of nitrogen flows and the integration of farm practice data relevant to both greenhouse gas and ammonia mitigation.
- A method to prioritise further mitigation activity and collation of farm practice data to minimise the uncertainties in emission projections to 2050 for analysis of policy outcomes.

The methane project (AC0115) will deliver a set of emission factors for different livestock species (focusing on cattle and sheep) and breeds/genotypes, under a range of different farm systems and representative business structures. This will also assess the effects of nutrition (basal forages, concentrate supplements, and feed additives). The nitrous oxide project (AC0116) aims to better reflect management systems within the UK, to take account of the range of soil types and climate, and take account of potential mitigation methods. This entails a move from what is essentially a Tier 1 structure (with some country-specific activity data) to a Tier 2 structure using country-specific emission factors (EFs) and improved activity data, and eventually towards a Tier 3 approach.

Another Defra project is just underway to examine the impacts of interventions in cattle health on GHG emissions Study to model the impact of controlling endemic cattle diseases and conditions on national cattle productivity, agricultural performance and greenhouse gas emissions FFG1016.

3.3.3 Attribution: FFBC survey

The third aspect addresses the issue of attribution and the need to estimate the effect of the FFBC programme on GHG changes via an FFBC specific survey. This would focus on the effectiveness of the delivery mechanism rather than methods, but would capture activity and behavioural aspects to inform the programme going forward.

As mentioned there are multiple drivers to changes in farm practice including the uptake of GHG-reducing MMs and it is difficult to isolate impacts from single drivers. Given that the FFBC programme is focussing on the most cost effective of MMs (i.e. they are expected to contribute to the financial viability of a farm that implements them) identified in prior projects, such MMs might be expected to be implemented by those seeking to improve profitability. A number of barriers to the uptake of such MMs have been identified (e.g. Defra FFO201 Market Segmentation in the Agricultural Sector: Climate Change), thus necessitating programmes such as FFBC.

One way of assessing the FFBC programme contribution to changes in agricultural emissions could be to survey a group of farmers who have been exposed to the scheme and a group who have not. The survey would seek to tease out the differences in uptake between the two groups over time. Differences in uptake should help estimate the contribution that the FFBC Programme makes to GHG changes. Various assumptions would have to be made (e.g. how FFBC information diffuses and influences across the sector) and any results should be viewed in this context – they would be an estimate of attributed uptake subject to uncertainty.

3.4 Conclusions

The ability of existing data to describe the uptake and GHG impact of the MMs prescribed by the FFBC is reasonable, in that the majority of the traffic lights are amber. This means that whilst the existing data sources are not always ideal, they will often provide a crude estimate of uptake and GHG impact (apart from those targeting the retention of soil carbon). The limitations of the data are increased if it is required to attribute the uptake of GHG impact specifically to the FFBC programme, rather than track change at country level.

There are three aspects to improving the capacity to monitor the impact of the FFBC programme, namely tracking farm practice activity, improving the robustness of the emissions factors related to such activity, and attribution of emissions changes to FFBC. The data from ongoing inventory-related research projects and a regular farm practice survey would improve the ability to monitor MM activity and emissions in the medium term (2-4 years) but will not address to the question of FFBC attribution. For the latter a discrete survey on the use and effectiveness of FFBC would be needed to differentiate between the drivers of MM uptake.

Appendix 1: Mitigation method fact sheets

Using energy and fuels efficiently

MM1 Carry Out an Energy Audit

Energy audits are a first step in reducing energy use. They should be carried out by a trained practitioner and are available from the Carbon Trust and other private consultants, sometimes linked to renewable energy opportunities. They comprise a list of all sources of energy use on the farm and the amounts used, preferably broken down to at least quarterly periods to give some guidance on the nature of energy usage, for example showing increased fuel use during the main cultivation period. Along with the record of energy use, they should provide recommendations on how to improve the efficiency of energy use. This may include switching energy supplier, changing tariffs or using a different energy source. Other practical examples may be:

- Use of (Co-operative) central dryers / crop storage where greater efficiencies per tonne of produce are derived.
- Appropriate machine complement for workload e.g. correct tractor sizes for the size of implement.
- Use of Machinery Rings to utilise best available / appropriate fuel efficient machines.

The findings of the audit should be included in a written report that can be used to underpin management decisions on how energy use can be reduced or re-directed, for example to non-fossil fuels. In themselves, the audits have no GHG impact.

a) MM flow to GHG impact

Baseline	Energy use not monitored		
	↓		
Mitigation method application	Record and collate energy use – electricity, petroleum based fuels and wood		
	Electricity	Petroleum based fuels	Wood and other biomass
	↓		
	Establish divisor e.g. head, hectares etc.		
	↓		
	Calculate emissions from use and units. Draw up action plan for improvements		

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Potential fossil fuel savings					

b) MM characterisation and measurement

What does it mean?	Take note of energy and fuel use and work out use per unit of production or land		
Farm input	No change at this stage, this is establishing a baseline		
Farm output	No change		
Farm practice	Establish energy use on farm and per unit.		
Ecosystem service impacts*	Regulating	Supporting	Cultural
	NA	NA	NA
Measurement	Primary. The number of energy audits at farm level by robust farm type and size. Collection every 2-3 years would be sufficient to capture changes in the rate of uptake of energy audits (positive or negative). Proportion of farms undertaking energy audits to total number of farms in Scotland to be reported.		
Building blocks	Primary **Number of farm energy audits (new)** — **Total number of farms (new)** — **Farm typology**		
Data requirements	Primary • The total number of energy audits performed at farm level in Scotland, by robust farm type and standard labour requirement (size). • Total number of farms in Scotland by robust farm type and standard labour requirement.		
Existing data sources	Primary • The Carbon Trust in Scotland provides specialist support in the metering and monitoring of energy use. The Carbon Trust hold records of energy audits by business type, but they are not publicly available. Requests for disclosure should be made to info@customercentre.carbontrust.co.uk. • Register of holdings held by the Rural Payments Agency provides the number of active farms in Scotland. • June survey/ census for the number of farms by type and size.		
Potential for new data sources	Survey every 2-3 years to establish whether or not at farm level an energy audit has been undertaken, stratified by robust farm type and size. This will allow uptake of the mitigation measurement in Scotland to be determined in a robust statistical manner.		

Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **amber**. The Carbon Trust hold records of energy audits in Scotland, but they are not publicly available.. Requests for disclosure should be made to info@customercentre.carbontrust.co.uk. However, some farm energy audits will be privately commissioned and will not necessarily be recorded by the Carbon Trust.

MM2: Implementation of an energy audit recommendation

This MM is a follow on from the energy audit, which in effect is a follow up audit when one or more of the recommendations from the original audit have been carried out and a change in energy use is able to be demonstrated, for example a reduction in fuel use over the year.

Whilst the recommendations may involve investment in capital items such as meters, they will usually result in savings in energy use and therefore financial savings to the business, so there should be few barriers to uptake. However, uptake may be incentivised through support schemes, including SRDP capital grants.

Part of this MM – agricultural fuel use – will be allocated to the agricultural sector in the GHG inventory. However, other energy use such as electricity consumption cannot presently be attributed to the agricultural sector under the current inventory framework.

a) MM flow to GHG impact

Baseline	Current unplanned energy use		
	↓		
MM application	Introduction of improved controls or reductions		
	1) Action to reduce usage – e.g. turn off lights when not in use	2) Action to purchase equipment to avoid waste, e.g. low energy light bulbs or variable speed drive for electric motors	3) Re-design process to minimise energy use

	CO_2		N_2O		CH_4	
GHG impact	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Reduced fossil fuel	Reduced fossil fuel				

b) MM characterisation and measurement

What does it mean?	Modifying energy use by increasing efficiency of present system, buying new equipment or changing the system
Farm input	No change in first two, but third may involve reduced production but at reduced input Lower energy costs
Farm output	Generally no change in output - energy use reduced per unit of production

<table>
<tr><td>Farm practice</td><td colspan="3">Improved energy awareness</td></tr>
<tr><td rowspan="2">Ecosystem service impacts</td><td>Regulating</td><td>Supporting</td><td>Cultural</td></tr>
<tr><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Measurement</td><td colspan="3"><u>Primary</u>. The total number of implemented energy audit recommendations expressed as a proportion of the total number of farm energy audits is required to measure uptake of this MM.

Energy audit recommendations can include reduced usage, reduced waste from updated equipment/systems, re-designed systems. Instances of farm implementation of energy audit recommendations by robust farm type and standard labour requirement (size) to be reported as a proportion of the total number of farm energy audits undertaken. Measurement of energy audit recommendation adoption to be made every 2-3 years to enable the capture of MM application.

<u>Secondary</u>. Direct energy use should also be estimated approximately every 2-3 years to capture subsequent decrease in direct energy use from fossil fuels due to energy audit recommendations. Ideally farm level data should be collected and kept together to help identify a cause-effect relationship.</td></tr>
<tr><td>Building blocks</td><td colspan="3"><u>Primary</u>
Number of farm energy audits (new) | Number of farms adopting energy audit recommendations (new) | Farm typology

<u>Secondary</u>
Direct energy use in agriculture</td></tr>
<tr><td>Data requirements</td><td colspan="3"><u>Primary</u>
• The total number of farms in Scotland, by robust farm type and standard labour requirement that have adopted at least one energy audit recommendation.

• Annually, the total number of energy audits performed at farm level in Scotland, by robust farm type and standard labour requirement.

<u>Secondary</u>
• The total use of fossil fuel energy at farm level, expressed in GJ/ha/yr and disaggregated by fuel type (oil, natural gas, coal, electricity, derived heat) and robust farm type and size.</td></tr>
</table>

Existing data sources	Primary • Records of support under the Scotland Rural Development Programme provide instances of implementation of energy audit recommendations under the following options LMO4 – Modernisation through electronic data management for Agriculture RP5 – Restructuring Agricultural Businesses (Axis 1) RP9 – Renewable Energy Agriculture (Axis 1) RP14 – Provision and upgrading of infrastructure (Axis 1) • The Carbon Trust hold records of energy audits by business type, but they are not publicly available. Requests for disclosure should be made to info@customercentre.carbontrust.co.uk. Secondary • The Department of Energy and Climate Change (DECC) collate statistics on energy consumption by fuel type (including renewables). Publically available statistics are not broken down by both sector (agriculture) and to NUTS 1 (Scotland) at present due the small number of sites. http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/source/renewables/renewables.aspx
Potential for new data sources	Primary • Follow up survey to farm energy audits establishing the adoption of energy audit recommendations (Carbon Trust). Recommended repeat survey at the same rate of energy audit uptake. Secondary • A survey of farms to measure changes in fossil fuel energy use before and after the implementation of energy audit recommendations would be beneficial.
Conclusions	Primary The potential for existing data sources to capture uptake of the measure is **red**. There is no known comprehensive source of data describing implementation of energy audit recommendations. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct CO_2) as a result of implementation of this measure is **amber**. National statistics on direct energy consumption by fuel type are available and could capture overall changes in energy consumption at a sector level, but in order to relate changes in consumption to the implementation of an energy audit recommendation on farm, energy use data should ideally be collected on farm.

Developing renewable energy

MM3: Energy generation e.g. capacity put in place

In order to fulfil this measure, famers would be required to install renewable energy capacity. This measure does not specify that renewable capacity must directly replace fossil fuel capacity, and therefore it could be installed as part of an expansion plan. A lower level of investment may be available in the use of crop residues / wood for firing drying plant e.g. drying grain.

Given the costs associated with renewable energy generation, uptake of this option in is likely to be dependent on support schemes. There are a number of support schemes available for renewable energy installation which farmers can choose from, including capital grants (through SRDP) and feed-in-tariffs once the capacity is up and running.

Other potential barriers to uptake besides cost include planning considerations, although not all installations will require planning consent (and therefore not all renewable installation will be captured on planning databases). Anaerobic digestion usually requires some form of solids to be added to the slurry, such as forage crops or food waste. If it is the former, the farm may need to provide this input, with a subsequent reduction in land available for other uses.

The main GHG impact will the subsequent fall in fossil fuel consumption, or fossil fuel consumption avoided if part of an expansion plan. The overall impact will need to take account of the emissions concerned with installation; therefore GHG savings may not be immediate.

The GHG inventory records energy use, but in the case of energy generation, it is not be possible to attribute this reduction to the agriculture sector.

a) MM flow to GHG impact

Baseline	Energy from fossil sources
	↓
MM application	Install renewable energy generation Wind, PV, Hydro, Ground source, AD
	↓
GHG impact	Reduced fossil energy use direct CO_2

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Reduced fossil fuels				Reduction from AD process	

b) MM characterisation and measurement

<table>
<tr><td>What does it mean?</td><td colspan="3">Installation of renewable source of energy, the capital investment, planning process and installation</td></tr>
<tr><td>Farm input</td><td colspan="3">Reduce input of fossil energy costs
Additional employment</td></tr>
<tr><td>Farm output</td><td colspan="3">Unlikely to change</td></tr>
<tr><td>Farm practice</td><td colspan="3">Management of renewable energy equipment, improved waste management (AD)</td></tr>
<tr><td rowspan="2">Ecosystem service impacts</td><td>Regulating</td><td>Supporting</td><td>Cultural</td></tr>
<tr><td>Noise regulation ↓</td><td>Water cycling ↓</td><td>Aesthetics ↓</td></tr>
<tr><td>Measurement</td><td colspan="3"><u>Primary.</u> The measurement of uptake of this MM should be by quantification of installed RE generation capacity on farms. This should be updated every 5 years since sites would usually need to go through the planning process and therefore uptake will be slow.

<u>Secondary.</u> Direct energy use from fossil sources should also be estimated approximately every 5 years to capture subsequent decrease in direct (fossil fuel) energy use due to increases in RE generation. Ideally farm level data should be collected and kept together to help identify a cause-effect relationship.

Recommended units for both measures are energy use/ generation per unit of production per annum to enable extrapolation of survey data on a production basis. This will also account for the fact that the installation of renewable energy generation capacity on farm may be accompanied by expansion of production, and thus may result in no net change in fossil fuel use at a farm level.</td></tr>
<tr><td>Building blocks</td><td colspan="3"><u>Primary</u>
Renewable energy production: agriculture | Crop yield by crop type | Livestock number by species | Meat production by species | Egg production by species | Milk production by species
<u>Secondary</u>
Direct energy use in agriculture</td></tr>
<tr><td>Data requirements</td><td colspan="3"><u>Primary</u>
• Installed capacity of on-farm renewable energy installations, expressed in GJ/unit production/yr and disaggregated by technology type (wind, PV, hydro, ground source, AD).
• Cereal, potato, livestock, meat, egg and milk production (Kg, head, #, L) to be collected at a farm level.
<u>Secondary</u>
• Total use of fossil fuel energy at farm level, expressed in GJ/unit</td></tr>
</table>

	production/yr and disaggregated by fuel type (oil, natural gas, coal, electricity, derived heat).
Existing data sources	Primary • The Rural Priorities Scheme in the Scotland RDP (2007-13) includes an option for 'Renewable Energy – Agriculture', which provides a grant for the purchase and installation of small scale RE capacity (up to 250kW) where applicants can demonstrate the generation capacity is primarily for agriculture related activity. • DECC's RESTATS website provide statistics on renewable energy generation/ capacity by UK country, as well as a planning database that lists operational projects and those in planning. Data are not subdivided by agriculture/ non-agriculture in the statistics or the database. https://restats.decc.gov.uk/cms/welcome-to-the-restats-web-site/ • Scottish Agriculture output, input and income statistics – presents information on outputs (e.g. crops, finished livestock, livestock products), both in terms of monetary value and 000 tonnes crops/ carcase weight, million litres of milk, millions of eggs. Secondary • The Department of Energy and Climate Change (DECC) collect statistics on energy consumption by fuel type (including renewables). Publically available statistics are not broken down by both sector (agriculture) and to NUTS 1 (Scotland) at present due the small number of sites. http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/source/renewables/renewables.aspx • Farm Accounts Survey – energy consumption could be estimated from expenditure data in the FAS in combination with energy prices. This would mean that the necessary data would be available with annual updates, however the survey is only representative of the main farm types (those with the highest land use) and the calculations would be based on a number of assumptions.
Potential for new data sources	Primary • A planning database that lists larger operational **agricultural** projects would be beneficial to measure the uptake of this MM. • Additional question on the census which asks for details of renewable energy installations, expressed in GJ/unit production/yr and disaggregated by technology type (wind, PV, hydro, ground source, AD). Secondary • A survey of farms with RE installations would be beneficial to measure changes in fossil fuel energy use before and after

	installation, along with any changes in agricultural production. • Defra introduced an Energy Module into their Farm Business Survey[8], which may be possible to reproduce in Scotland. The FAS is Scotland has a much smaller sample size than the FBS in England, so this may not be feasible unless the whole FAS sample were to be used for this additional information.
Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **amber**. The most suitable data source is the uptake of the option in the Rural Priorities Scheme. This will, however, only capture installations that have taken up this grant. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct CO_2) as a result of implementation of this measure is **amber**. National statistics on energy consumption by fuel type are available, as are national statistics on agricultural production, but in order to relate changes in consumption to RE installation on farm, energy use data should ideally be collected on these farms.

[8] Analysis of the 2007/8 Defra **Farm Business Survey Energy** Module

MM4 Fuel production e.g. biomass – sequestration and reduced fossil fuel

This measure promotes the cultivation of biomass crops such as miscanthus, willow and poplar which can then be used for energy generation in the place of traditional fossil fuels. Wood chip and wood pellets used for biomass are mainly produced from small round wood and sawmill co-products. Some use is made of forest residues (e.g. brash) but this is more difficult. The rising demand for woodfuel is opening the potential for producing wood from areas of woodland that have previously been uneconomic to harvest because of (e.g.) access problems.

On the farm, cultivation of biomass may take land out of cultivation for crops and grazing, but where possible, farmers are likely to seek to grow biomass crops on marginal land that has limited agricultural use, therefore minimising any production effects. In forestry, in many cases, tree planting will take place on clear felled areas so will not take other land out of production. Farmers may also seek to incorporate biomass production into the farm system – for example, the establishment of woodland has the additional potential advantage of providing shelter for livestock.

The key GHG impact from biomass (reduced fossil fuel use) will take place off farm and is not the focus of this measure. However, depending on the existing use of the land and the type of biomass crop planted, biomass planting may affect soil organic carbon. For arable biomass crops (e.g. Miscanthus and coppice willow) soil disturbance occurs during cultivation at planting and possibly if mechanical weed control is required or soil loosening following any harvest traffic. However, SOC losses will be lower than if used for traditional cropping and pesticide and fertiliser use should also be lower. Where grassland is used for biomass crops, net SOC losses will occur at establishment and fertiliser use may be higher. For forestry, the first few years following establishment may result in net emissions until the annual growth achieves a net sequestration.

The GHG Inventory will count land use changes, for example from grassland to forestry in the LULUCF chapter, but changes in type of crop/management regimes within each land use type will not be quantified in the Inventory.

Alongside FFBC, the Forestry Commission are active in promoting in advising biomass production, making it potentially more difficult to attribute uptake solely to FFBC.

a) MM flow to GHG impact

Baseline	Energy from fossil sources
	↓
MM application	Introduction of biomass production 1. replace arable 2. replace grass 3. replace woodland Miscanthus, short rotation coppice willow, trees

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
Previously agricultural crops	Reduced cultivations for biomass crops and reduced losses of soil organic carbon (SOC)					
Permanent grass	Increased cultivations on biomass crops and loss of SOC at planting					
Trees	Likely net emissions following establishment prior to net sequestration as growth develops after early years					

b) MM characterisation and measurement

What does it mean?	Replacing arable crops or grassland with biomass crops or timber for firewood. This will reduce food production in the case of arable land or reduce the land for stock to graze if grassland is used apart from the case of woodland for firewood managed as agro-forestry.
Farm input	Likely to reduce emissions where prior input use was greater. On cropped land, need to purchase feed that would have been grown. Lower fuel costs?
Farm output	May reduce output if grazed area is reduced.
Farm practice	May require change in balance of farm system

<table>
<tr><td rowspan="2">Ecosystem service impacts</td><td>Regulating</td><td>Supporting</td><td>Cultural</td></tr>
<tr><td>Water and soil quality (↑/↓)</td><td>NA</td><td>NA</td></tr>
<tr><td>Measurement</td><td colspan="3"><u>Primary.</u> The measurement of uptake of this MM should be by quantification of the area of agricultural land planted with biomass crops. This should be updated annually.

<u>Secondary.</u> The increase or decrease in fuel usage as a result of increased or decreased cultivations should also be measured annually to capture the subsequent change in CO_2 emissions due to the replacement of arable crops or grassland with biomass crops or timber. This could be measured at a sector level, but could not be attributed to the MM. Alternatively, factors for fuel use per unit area on the original land use and the new land use could be used to calculate the expected change in fuel use as a result of implementation of the measure.

Changes in soil organic carbon losses as a result of planting and changes in cultivation would also need to be calculated annually. This would require the use of factors or models for SOC loss by land use transition and continuing management covering emissions and sequestration due to changes in for example cultivation, crop residues, which are not currently captured in the Inventory.</td></tr>
<tr><td>Building blocks</td><td colspan="3"><u>Primary</u>
Crop area by crop type

<u>Secondary</u>
Land use change by type
Direct energy use in agriculture
Direct energy use by activity (new)
Soil properties: carbon loss</td></tr>
<tr><td>Data Requirements</td><td colspan="3"><u>Primary</u>
• Area of biomass crops planted (ha) by crop type (Miscanthus, SRC, trees)

<u>Secondary</u>
• Areas of cultivated land, grassland and woodland (ha) planted with biomass crops.
• Total use of fossil fuel energy for agriculture sector, expressed in GJ/yr and disaggregated by fuel type (oil, natural gas, coal, electricity, derived heat).
• Coefficients for energy consumption (GJ/ha) from cultivation/planting of arable crops, grassland, biomass crops.
• Coefficients for carbon loss (t/ha) from soils under arable land, grassland, woodland, biomass cropped land.</td></tr>
<tr><td>Existing Data Sources</td><td colspan="3"><u>Primary</u>
• Land Parcel land use data is collected as part of the annual IACS submission required by farmers claiming SFP or other area payments. Land-use codes available for use include ‘Short rotation</td></tr>
</table>

	coppice' and 'Miscanthus'. • The Rural Priorities Scheme in the Scotland RDP (2007-13) includes an option for 'Short rotation coppice of crops of willow or poplar'. Proposals for this option must demonstrate that they have established an end use for the produce (i.e. a fuel supply for RE products). • Questions on sources of renewable energy, including biomass, were included in the 2010 June Census. These questions were included to satisfy the requirements of the 2010 EC Farm Structure Survey (FSS). It is possible that these questions will be repeated in future FSS (every 3 years). • AEBIOM (European Biomass Association) produce statistics on renewable energy generation and the main feedstocks. Includes current land use for biofuels and energy output per ha (toe). This is a less reliable data source than the previous two, since it collates data from a variety of non-standard sources. Secondary • The Department of Energy and Climate Change (DECC) collect statistics on energy consumption by fuel type (including renewables). Publically available statistics are not broken down by both sector (agriculture) and to NUTS 1 (Scotland) at present due the small number of sites. http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/source/renewables/renewables.aspx • Emission factors for carbon loss for soils under grassland, cropland and forestry from the most recent LULUCF inventory submission.
Potential for new data sources	Primary • Inclusion of biomass crops in the June Agricultural Survey (if this is not done already) to provide data for the ~12,000 holdings which do not claim SFP and therefore do not complete IACS submissions.
Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **green**. Approximately 68% of holdings (representing 87% of the agricultural land area) in Scotland claim SFP and therefore provide IACS data on an annual basis. For the remainder, data on area of biomass crops could be obtained from the June Survey forms for 2010 and possibly also in future surveys. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct CO_2) as a result of implementation of this measure is **amber**. This relies on sufficient primary data and suitable coefficients from empirical or modelled data. At present, the scientific evidence to enable accurate quantification of carbon losses from soil under different vegetation types and land management practices is lacking, although crude estimates could be made for changes in emissions for replacement of grassland or woodland with biomass crops from the LULUCF inventory.

Locking carbon into soil and vegetation

MM5 Retain and conserve soils with high organic matter content (peatland, moorland, wetlands and semi-natural grassland)

As the title suggests, this MM is targeted on areas that are unimproved. The objective is to avoid losses soil carbon by not carrying out conventional actions historically seen as improvements, such as liming, draining, cultivating, fertilizing and seeding.

The main barrier to this MM is continued economic pressure on farmers to increase food production and lack of knowledge by farmers as to the damage resulting from intensification of high organic matter soils. That said, SRDP agri-environment schemes offer an incentive for farmers to retain and conserve soils with high organic matter content through continuation of appropriate land management, SRDP data also offers a key mechanism for monitoring active conservation of high organic matter soils.

In terms of GHG impacts, there will be no measurable decrease in emissions as this MM is focussed on emissions that can be avoided in the future. It is important in managing high organic matter soils to maintain continuous cover both to maintain peat growth and to avoid degradation, which can result in significant soil carbon losses. These GHG emissions are potentially very large if the MM is not followed, though only those where an actual land use change has occurred would appear in the current GHG Inventory

a) MM flow to GHG impact

Baseline	Extensively managed high organic matter land	
MM application	Peatland, moorland and wetlands	Semi natural grassland
	↓	↓
	Avoid drains or grips, avoid overgrazing	Avoid drains or grips, avoid overgrazing/poaching and do not fertilise

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	<u>Avoided due to reduced soil disturbance/drying out</u>					

b) MM characterisation and measurement

<table>
<tr><td>What does it mean?</td><td colspan="3">Avoid losses by not ‘improving’ these areas (draining, cultivating, fertilizing, and seeding).</td></tr>
<tr><td>Farm input</td><td colspan="3">None</td></tr>
<tr><td>Farm output</td><td colspan="3">Reduced potential output of livestock, loss of grazing and conserved grass</td></tr>
<tr><td>Farm practice</td><td colspan="3">Require no change in system</td></tr>
<tr><td rowspan="2">Ecosystem service impacts</td><td>Regulating</td><td>Supporting</td><td>Cultural</td></tr>
<tr><td>Flood control (↑)</td><td>Soil formation (↑)
Nutrient cycling (↑)
Water cycling (↑)</td><td>Recreation/tourism (↑)</td></tr>
<tr><td>Measurement</td><td colspan="3"><u>Primary</u>. The measurement of uptake of this MM should be by measuring the area of unimproved land (bog, shrub heath, unimproved grassland) on soils with a high organic content (peats and organo-mineral soils in Scotland). Firstly the baseline area of unimproved land on high organic soils should be estimated by overlaying the location of unimproved land with the location of soils with a high organic content and carrying out a spatial analysis in a GIS. Retention of unimproved land on soils with a high organic content can be estimated by repeating the measurement approximately every 5 years. This can then be expressed as a percentage of the baseline.
Alternatively, the area of extensively managed soils with high OC content, by robust farm type and size, could be measured directly.</td></tr>
<tr><td>Building blocks</td><td colspan="3"><u>Primary</u>
Soils properties: organic carbon content (new) | Land cover by type</td></tr>
<tr><td>Data Requirements</td><td colspan="3"><u>Primary</u>
• The spatial distribution of unimproved land (ha) at the finest spatial resolution available.
• The properties of the soil in terms of organic carbon content (%) should be obtained at the finest spatial resolution available.</td></tr>
</table>

Existing Data Sources	Primary • Land Cover Map – location and area of relevant natural and semi-natural broad habitats could be mapped from this dataset. A new dataset is released approx every 7 years to quantify change, but this may not be frequent enough to monitor the uptake of this MM. • Macaulay Soils Map (1:250,000) – the location of high carbon soils has been mapped using this dataset, which is the best resolution soils dataset available for Scotland. The ECOSSE[9] project assigned each of the mapping units to a major soil subgroup to map the distribution of peaty and organo-mineral soils in Scotland. • Monitoring data of grant aid under the Land Managers Options and Rural Priorities schemes. Options available under these schemes include “Management of Moorland Grazing”, “Moorland Grazings on Uplands and Peatlands”, “Wildlife Management on Upland and Peatland Sites”. Uptake of these options should be available from SG as land areas linked to individual land parcels. • June Census data will provide information on livestock density if linked to IACS land parcels. This information could be used as an estimate of grazing intensity on high organic matter land if overlaid with the soil carbon map.
Potential New Data Sources	• A survey to establish the area (ha) of soils with high organic content that is managed extensively would be beneficial. This should be stratified by robust farm type and size, repeated approximately every 5 years.
Conclusions	Primary The potential of existing data sources to successfully capture uptake of this measure is **amber**. Measurement of unimproved land on soils with a high organic content using the Land Cover Map, whilst direct and comprehensive, is limited to the temporal and spatial resolution (25m) stated and lacks any information about management. Some information about management (grazing pressure) could be estimated from June survey linked to IACS data, but this would not cover all of the mitigation measure applications. Alternative data sources, uptake of the options in the Rural Priorities and Land Managers schemes, will, however, only capture soils with a high OC managed under this grant.

[9] ECOSSE – Estimating Carbon in Organic Soils Sequestration and Emission. Final Report, March 2007

MM6 Restore soils with high organic matter content

Restoring soils with high organic matter content principally refers to changing management practices for areas of rough grazing and moorland that have been ‘improved’ through the use of fertilisers and higher output grasses.

In Scotland, this measure may lead to less available land for intensive grazing (although extensive grazing may still be possible).

The main GHG impact will be through reduced losses of soil organic carbon due to less soil disturbance and degradation. Fertiliser use could also fall if previously used to ‘improve’ the land. Although lower animal numbers could lead to absolute falls in CH4 emissions, these may also increase if this measure leads to long periods of high moisture levels, especially on previously improved upland/moorland, although the literature implies this may only be a temporary spike.

The GHG Inventory will pick up falls in methane due to lower animal numbers, but would be unable to distinguish falls in the other effects described above.

a) MM flow to GHG impact

Baseline	Drained rough grassland or heather moorland
	↓
MM application	Reversion to extensive grassland/heather moorland - reduction of fertiliser inputs (where previously applied)

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Reduced soil disturbance, erosion, and soil respiration, potential for sequestration					
	Potential for emissions export					

b) MM characterisation and measurement

What does it mean?	Blocking drains/grips and reducing fertiliser etc on marginal farmland		
Farm input	Reduced inputs of fertilisers.		
Farm output	Grazing potential reduced – fewer livestock related outputs		
Farm practice	Range of options – site dependent e.g. blocking of drains and ditches to raise water levels.		
Ecosystem service impacts	Regulating	Supporting	Cultural
	Flood control (↑)	Soil formation (↑) Nutrient cycling (↑) Water cycling (↑)	Recreation/tourism (↑)
Measurement	Primary. The measurement of uptake of this MM should be by the area of improved (drained and/or fertilised) agricultural land restored to extensive, un-drained and un-fertilised grassland or moorland on soils with high organic carbon content (peats and organo-mineral soils in Scotland[9]). First the baseline area of improved agricultural land on organic soils should be estimated by overlaying the location of improved grassland with the location of organic soils and carrying out a spatial analysis in a GIS. The area of this land restored to unimproved grassland or moorland should then be estimated approximately every 5 years and expressed as a percentage of the baseline area. Secondary. GHG abatement inferred from change in land-use using coefficients for CO_2 emissions from soils under improved (drained) grassland and under semi-natural grassland or moorland. This would require the use of coefficients for more detailed land-use categories than are reported in the LULUCF sector of the GHG inventory, since 'grassland' in LULUCF covers all types of land used for the grazing of livestock.		
Building blocks	Primary **Soil properties: organic carbon content (new)** | **Land cover by type** | **Land use change by type** Secondary **Soil properties: carbon loss (new)**		
Data Requirements	Primary • The spatial distribution of improved grassland (ha) at the finest spatial resolution available to be collected at baseline. • The properties of the soil in terms of organic carbon content (%) should be obtained at the finest spatial resolution available at baseline. • The area of land with high organic carbon content that is		

	undergoing reversion to its natural state (ha) should be collected at farm level, ideally annually. Secondary • Coefficients for carbon loss (t/ha) from drained organic soils under improved grassland and under unimproved semi-natural grassland/ moorland are required.
Existing Data Sources	Primary • Land Cover Map 2007 – location and area of improved grassland could be mapped from this dataset. • Macaulay Soils Map (1:250,000) – the location of high carbon soils has been mapped using this dataset, which is the best resolution soils dataset available for Scotland. The ECOSSE[10] project assigned each of the mapping units to a major soil subgroup to map the distribution of peaty and organo-mineral soils in Scotland. • Monitoring data for Rural Priorities (RP) Scheme – Management/ Restoration of Lowland Raised Bogs is an option that aims to bring lowland raised bogs (high OC content) into favourable condition. Requirements include ditch blocking work and ensuring that there is no cultivation or use of fertilisers. Uptake of this option in terms of land area will be available from SG. • Monitoring data for Rural Priorities (RP) Scheme – Moorland Grazings on Uplands and Peatlands is an option that aims to maintain and enhance a range of upland and peat habitats by promoting good soil management. This can include the blocking of moor grips with peat dams, and ditch blocking with plastic piling dams. Uptake of this option in terms of land area will be available from SG. Secondary • The ECOSSE[11] project developed a model to predict the impacts of changes in land use on GHG emissions from organic soils. In addition, module 4 of this project reviews the effects of land-use management (including drainage and grazing) on the release of DOM from organic soils. • Other published literature, e.g. JNCC, 2011[12]; Wallage *et al.*, 2006[13]; Jones and Donnelly, 2004[14]; Jones *et al.*, 2006[15]; Guo and Gifford, 2002[16]. • Countryside Survey 1978, 1998, 2007 – soil samples taken for CS allow quantification of topsoil C contents and change across all major UK land uses and allow the assignment of pressures and

[10] ECOSSE – Estimating Carbon in Organic Soils Sequestration and Emission. Final Report, March 2007
[11] ECOSSE – Estimating Carbon in Organic Soils Sequestration and Emission. Final Report, March 2007
[12] Joint Nature Conservation Committee (2011) Towards an Assessment of the State of UK Peatlands. JNCC Report No.445
[13] Wallage ZE, Holden J and McDonald AT. 2006. Drain blocking: An effective treatment for reducing dissolved organic carbon loss and water discolouration in a drained peatland. *Science of the Total Environment* **367,** 811-821.
[14] JONES, M. B., DONNELLY, A.(2004) Carbon sequestration in temperate grassland ecosystems and the influence of management, climate and elevated CO2, *New Phytol*., **164**, 423-439.
[15] JONES, S. K. et al. (2006) Carbon sequestration in a temperate grassland; management and climatic controls, *Soil Use Manage*., **22**, 132-142.
[16] GUO, L. B., GIFFORD, R. M. (2002) Soil carbon stocks and land use change: a meta analysis, *Global Change Biol.* **8**, 345-360.

	drivers to the observed changes, including land use and management, however there was no convincing evidence that changes in land cover and intensity of management significantly affected topsoil C concentration, perhaps with the exception of soil pH and moisture (Emmett *et al*., 2010. Chapter 3 in *An Integrated Assessment of Countryside Survey data to investigate Ecosystem Services in Great Britain.* CS Technical Report No. 10/07). This study did not specifically investigate the effects of peatland restoration on soil carbon loss, and therefore has limited application here.
Potential New Data Sources	None identified
Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **green**, if we assume that land managers undertaking changes in management practice to restore soils with high organic carbon content are taking up grant aid under the Rural Priorities Scheme. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct CO_2) as a result of implementation of this measure is **amber**. At present, the scientific evidence to enable accurate quantification of carbon losses from soil under different vegetation types and land management practices is lacking and the impact of restoration can take many years, however models and emission factors are available that could be used to estimate GHG abatement as a result of changes in management of organic soils.

MM7 Manage existing woodland and create new woodland

Many small parcels of woodland on farms are given little management time and offer little in the way of economic or environmental value. This can be improved through active management, resulting in increased value of products such as wood fuel and saleable timber with additional benefits for biodiversity. Woodland creation is more likely to take place on land where economic returns are marginal with limited impact on food production. This MM is similar to MM4 in terms of wood fuel production and substitution of fossil fuel by wood, particularly with correct use of timber species. This would involve, for example, the use of Sitka on wetter areas and larch on dryer areas to maximise yield class of timber to target potential yield class to maximise timber growth / carbon sequestration.

Carbon dioxide emissions from woodland SOC are of the order of 2-5% for common, low impact establishment practice and woodland types. Net sequestration may be as long as 10-15 years but likely to be significantly shorter on agricultural units. Indirect emissions will reduce significantly in the case of new woodland compared with cropped land.

The GHG Inventory will count changes from grassland and cropland to forestry in the LULUCF chapter, but changes in management within these land uses will not be quantified in the current Inventory.

Alongside FFBC, the Forestry Commission are active in promoting in advising biomass production, making it potentially more difficult to attribute uptake solely to FFBC.

a) MM flow to GHG impact

Baseline Unmanaged and no new woodland

↓

MM Application

Manage existing
- Record current state of woodland and immediate management needs
- Fencing repairs to keep stock out
- Select trees to grow and remove others – poor specimens, dead and dying and under storey

Create new
- Select planting area
- Plan new woodland
- Check grant aid availability
- Plant trees and fence around

GHG impact

CO_2		N_2O		CH_4	
Direct	Indirect	Direct	Indirect	Direct	Indirect
<u>Net emissions soil/sequestration. at establishment to 12 yrs</u>	Reduction for new woodland				

Emissions export if farmed area reduced

b) MM characterisation and measurement

<table>
<tr><td>What does it mean?</td><td colspan="3">Many woodland areas on farms are neglected and uneconomic. Any commercial trees should be checked for condition and others removed to allow effective growth of the commercial trees. The under storey might be cleared to avoid loss of nutrients to uneconomic growth or left where biodiversity is relevant or used as agro-forestry if relevant.

New planting needs to be planned and correctly carried out. Grant aid should be sought.</td></tr>
<tr><td>Farm input</td><td colspan="3">Time, fencing materials</td></tr>
<tr><td>Farm output</td><td colspan="3">Reduced if new woodland on productive farmland. Increased sales through extracted firewood for both. For existing woodland, there is a potential loss of shelter for stock may need buildings and bedding</td></tr>
<tr><td>Farm practice</td><td colspan="3">New practices introduced for woodland management and creation</td></tr>
<tr><td rowspan="2">Ecosystem service impacts</td><td>Regulating</td><td>Supporting</td><td>Cultural</td></tr>
<tr><td>Flood control, water quality ↑</td><td>Nutrient and water cycling ↑</td><td>Recreation and tourism, aesthetic ↑</td></tr>
<tr><td>Measurement</td><td colspan="3"><u>Primary</u>
The area of managed woodland (ha) at farm level is required to measure uptake of the first part of this MM; the management of existing woodland. This should ideally be estimated annually.
The area of new (created) woodland (ha) at farm level is required to measure uptake of the second part of this MM; the creation of new woodland. This should ideally be estimated annually.
<u>Secondary</u>
The increase in the sequestration of carbon by the planted or managed woodland on an area basis should be calculated to measure the impact of uptake of this measure on direct CO_2 emissions. This will change over time - there are carbon dioxide emissions from woodland SOC at establishment, then reduce to a net sequestration as growth develops, so should ideally be calculated annually. The factors will also depend upon the tree species, the yield class, the site conditions and the management.</td></tr>
<tr><td>Building blocks</td><td colspan="3"><u>Primary</u>
Land cover by type \| Land use change by type \| Area of managed woodland (new)
<u>Secondary</u>
C sequestration: woodland (new)</td></tr>
</table>

Data Requirements	Primary • Area (ha) of managed woodland. • Area (ha) of created woodland. Secondary • Factors for C sequestration by tree species, age and soil type
Existing Data Sources	Primary • Monitoring data of grant aid under the Land Managers schemes. Options available under this scheme include "Small scale woodland creation", "Management of small woodlands". Uptake of these options may be available from SG as land areas, which may be linked to individual land parcels. • The June Agricultural Census/Survey provides a time series of estimates of change in land use from agricultural to woodland. Spatial information on land use is available from IACS land parcel data. Secondary • The Forestry Commission has developed tools (under Project Carbon Sequestration) to help estimate the amount of carbon in a woodland[17]. Carbon Lookup tables predict the rate at which carbon will accumulate in various forest types given various site conditions. These provide estimates of the amount of carbon that is likely to be sequestered per hectare over a given time period. Estimates are provided by species, spacing, yield class, management (thinned or not thinned) and time period. To further enhance the accuracy of woodland carbon estimates, adjustment values are being developed to allow changes in soil carbon levels to be accounted for.
Potential for new data sources	None identified
Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **green**. The most suitable data source is the uptake of the relevant option in the Land Managers scheme. This is based on the assumption that land managers creating or managing woodland will claim subsidy under the RDP. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct CO_2) as a result of implementation of the measure is **green**. The Forestry Commission's look-up tool[18] provides a simple means of estimating sequestration assuming the input variables are known.

[17] http://www.forestresearch.gov.uk/website/forestry.nsf/byunique/infd-8jue9t
[18] http://www.forestry.gov.uk/forestry/INFD-8JUE9T

MM8: Reduced till on suitable land

Reduced till refers to a change of cultivation practice on arable land away from ploughing. This is applicable to medium to heavy textured soils, since light soils require far less draught where ploughing is used to avoid compaction or over-consolidation. This is not a traditional practice in Scotland but has increased in prevalence recently.

Many farmers have moved to reduced tillage where they can due to the improvements in timeliness and reductions in energy use. Barriers to reduced till in place of ploughing include the need for investment required for reduced till equipment where a plough system is already in place and an element of resistance to moving from 'traditional' practice. It is best applied to land that can maintain yields thus not leading to emissions export.

With less soil disturbance, soil carbon may increase until the land is ploughed again in order to deal with any build up of weeds, pests or disease. So on average, soil carbon may be improved, but there is little current evidence and lasting carbon gain is uncertain. For soils not at their plastic limit, reduced till and zero till can lead to reduced SOC losses and potentially reduced N_2O losses. However, in wet conditions this can lead to soil compaction with consequent increases in N_2O losses. The effects will depend on the condition of the soil prior to reduced till and soil moisture at cultivation.

Additional benefits include improved biodiversity and worm activity.

The main GHG impact of this MM is to reduce the exposure of soil to atmospheric oxygen with consequent losses of soil carbon.

Any changes in cultivation technique will not show in the Inventory because the land is still cropland.

a) MM flow to GHG impact

Baseline	Ploughing ↓	
MM application	No-till – direct drill	Min-till – some degree of soil disturbance, <u>not</u> inversion

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Reduced fuel use. **<u>Reduced SOC losses due to disturbance</u>**		Minor reduction in soil losses (reduced exposure)?	Reduced leaching losses		Minor reduction in soil losses?

b) MM characterisation and measurement

<table>
<tr><td>What does it mean?</td><td colspan="3">Replacing ploughing with discs, sub-cast system or direct drilling. Relevant areas need to be mapped</td></tr>
<tr><td>Farm input</td><td colspan="3">Reduced fuel usage, reduced wear and tear on machinery, reduced labour input (although labour is a fixed cost).

Might end up with higher weed control costs especially if black-grass is a problem</td></tr>
<tr><td>Farm output</td><td colspan="3">Should be same as ploughing, depends on season +/-. Suitability may vary with season and conditions and reduced till may lead to increase in slumping and reduced yield, risk of erosion on weakly structured soils.</td></tr>
<tr><td>Farm practice</td><td colspan="3">Not a traditional practice in Scotland, where light land encourages ploughing because it opens the land and avoids seedbed problems.</td></tr>
<tr><td rowspan="2">Ecosystem service impacts</td><td>Regulating</td><td>Supporting</td><td>Cultural</td></tr>
<tr><td>Soil and water quality ↑, if carried out under Best Management Practice (BMP)</td><td></td><td></td></tr>
<tr><td>Measurement</td><td colspan="3"><u>Primary</u>
The area of land subject to reduced or zero tillage (ha) at farm level is required to measure uptake of this MM. This should be expressed as a proportion of the area of land suitable for zero or reduced tillage. Ideally this should be measured every 2-3 years.
<u>Secondary</u>
CO_2 losses from soils may vary due to cultivation method, but there is little conclusive data available at present. Emissions factors will be required for degree of reduced till</td></tr>
<tr><td>Building blocks</td><td colspan="3"><u>Primary</u>
Area reduced soil tillage
Area zero soil tillage
Soil properties: suitable reduced till (new)
<u>Secondary</u>
Soil properties: carbon loss (new)</td></tr>
</table>

Data Requirements	Primary • Total area (ha) of land suitable for reduced or zero tillage is estimated by quantifying areas of soils suitable for reduced or zero tillage for Scotland. • Area (ha) of land subject to reduced or zero tillage at farm level, by robust farm type and size. This to be extrapolated to a national figure by farm type and size. • The proportion of land cultivated using reduced or zero tillage is then estimated by dividing the area of land (ha) *subject* to reduced or zero tillage by the area of land (ha) *suitable* for reduced or zero tillage. Secondary • Emissions factors for ploughed, reduced tilled and zero tilled arable land.
Existing Data Sources	Primary • Area (ha) of land cultivated using reduced and inversion tillage is recorded in the one-off Survey of Agricultural Production Methods. • Macaulay Soils Map – the location of soils suitable for reduced or zero tillage could be mapped using this dataset, which is the best resolution soils dataset available for Scotland.
Potential New Data Sources	Primary It is recommended that a regular farm practice survey such as SAPM be undertaken to establish the area of land subject to inversion, reduced or zero tillage. To be repeated every 2-3 years to capture changes in tillage systems. Secondary Emissions factors for different till practices via research
Conclusions	Primary The potential for existing data sources to successfully capture uptake of this measure is **amber**. The area of land cultivated using reduced or inversion tillage is recorded in the Survey of Agricultural Production Methods. However, this is currently a one-off survey. This would be green if the survey were to be repeated. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct CO_2) as a result of implementation of this measure is **red**. This will be dependent on the necessary factors becoming available in the scientific literature.

MM9 Incorporating crop residues

In Scotland all crop residues are incorporated except for straw which is generally cycled through animal production. The object of the MM is to cultivate the crop residues into the soil in order to reduce the likelihood of soil erosion from arable land and therefore emissions through oxidation of soil organic matter. When carried out in suitably dry conditions, no additional nitrogen will be required and crop establishment will not be affected. In the long term, SOC may increase. However, in a wet season, crop residues can lead to reduced N availability, where some farmers may apply around 25kgN/ha. This does not necessarily increase N_2O emissions. A further consequence of a wet season may be additional wheelings resulting in an increased risk of soil erosion.

Incorporating crop residues increases organic matter content, water retention and reduces soil erosion.

Barriers to uptake include resistance to changing current practice where straw is baled to supply livestock farms with animal bedding, and the consequent loss of income. This MM may not popular in mixed farms where the straw is in high demand, and is eventually returned to the land in manures. In wet conditions, they can give problems for cultivations, increases in slugs and other pests and diseases, result in anaerobic layers and poor germination, hence they are not so popular in Scotland where hauling straw from east to west suits both arable and livestock systems. In addition, where straw is not removed, there can be problems with the following crop due to difficulties with incorporation.

Other impacts would occur in root crop areas, especially carrots where straw is used for winter bedding in the field to avoid frost damage. If this straw were to be incorporated at source, the roots would need to be harvested and stored in buildings. These may require significant capital expenditure to bring them up to current requirements and increase demands for capital funding, for example, from SRDP. Having said that the straw used for winter bedding of root crops is generally incorporated after use, increasing soil organic matter, but at a different location.

The GHG impact will be a reduction in erosion and the consequent loss of soil organic carbon, but a negative impact would be increased haulage emissions from new sources of straw for livestock in the west.

a) MM flow to GHG impact

Baseline	Crop residues removed, not incorporated
	↓
MM application	Straw not baled, but chopped and incorporated

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Net reduction in fuel use in baling and carting, but smaller increase due to chopping. **Potential reduction in erosion and SOC losses.**	Can lead to increased N use at establishment	May increase if cultivations increase due to residues & compaction			

b) MM characterisation and measurement

What does it mean?	Many farms in the eastern parts of Scotland sell straw for livestock bedding to farms in the west. The additional field operations can lead to wheeling damage and soil erosion. By incorporating straw, crop residues are cultivated back into the soil and help to retain moisture, condition the soil and avoid erosion. Potentially, increased soil organic matter		
Farm input	Reduced fuel use in straw clearance and reduced erosion and easier cultivation should reduce future costs in dry conditions. In wet years, incorporating crop residue can be difficult potentially leading to soil problems such as compaction and anaerobic conditions.		
Farm output	Loss of sale of straw		
Farm practice	Need to ensure crop residues are able to be cultivated into soil without causing problems		
Ecosystem service impacts	Regulating	Supporting	Cultural
	Flood control 🡅 (improved water retention)	Soil formation 🡅 (reduced erosion)	
Measurement	Primary. The area of agricultural land subjected to crop residue incorporation, expressed as absolute area and proportion of that suitable (combinable cropped land) is required for the measurement of uptake of this mitigation measure. This should ideally be measured		

	every 2-3 years. <u>Secondary</u>. Emissions factors for incorporation and non-incorporation of crop residues
Building blocks	<u>Primary</u> Straw management · Crop area by crop type · Farm typology <u>Secondary</u> Soil properties: carbon loss (new)
Data Requirements	<u>Primary</u> • Land area (ha) with a crop type suitable for the incorporation of crop residues (wheat, etc). • Land area (ha) subject to the incorporation of crop residues as a proportion of the land area suitable for the incorporation of crop residues (ha) by robust farm type and size to enable extrapolation to national level. • Total national area subject to crop residue incorporation, expressed as an absolute figure (ha) and proportion of the land suitable. <u>Secondary</u> • Emissions factors for incorporation and non-incorporation of crop residues
Existing Data Sources	<u>Primary</u> • Areas (ha) of agricultural land subject to crop residue incorporation are recorded in the one-off Survey of Agricultural Production Methods. • Cropping statistics are provided by the June Agricultural Census/Survey. <u>Secondary</u> • Current emissions factors for LUC unlikely to be sufficient
Potential New Data Sources	<u>Primary</u> • It is recommended that a regular farm practice survey (such as SAPM) be undertaken to establish the area of land subject to crop residue incorporation. To be repeated every 2-3 years to capture changes in management. <u>Secondary</u> • New emissions factors to show change due to crop residue incorporation by research.

Conclusions	Primary The potential for existing data sources to successfully capture the uptake of the measure is **amber**. This would be green if the SAPM were to be repeated. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct CO_2) as a result of implementation of this measure is **red**.

MM10 Growing cover crops

Cover crops are sown following the removal of the main arable crop in order to provide a crop canopy to protect the soil from erosion or to limit weed development prior to the establishment of following crop. Where autumn ploughing is current practice, the land is left bare over the winter and is at risk of erosion and loss of nutrients. Spring cultivations can be easier with a frost tilth allowing timely drilling of the crop.

When cover crops are introduced, the cultivations for the spring crop are transferred to autumn without the benefit of the winter tilth formation, so more work can be required to break down the soil. In spring, the cover crop needs to be ploughed in with the risk of soil damage in order to achieve good timeliness of the spring crop. However, this has reduced the risk of erosion, loss of nutrients and reduced emissions from the bare earth. Timing is important and cover crops need to be established early to avoid soil damage. This may lead to difficulties in potato and wheat crops due to their relatively late maturity.

There is also the additional benefit of over winter cover and feed for wildlife.

The main barrier to the routine use of cover crops is that they offer limited opportunity in most areas of Scotland due to the short season.

The main GHG impact on decreased losses from soil organic carbon will not show up on the inventory. The only inventory impact will arise from changes to fuel use as a result of establishment of cover crops.

a) MM flow to GHG impact

Baseline	Cover crops not grown ↓
MM application	Cover crops grown ↓ Cover crops established in autumn in fields intended for spring crops ↓ Establish by allowing field to ‘green up’ or broadcasting tail corn.

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	SOC decreased losses. Fuel use: possible overall increase		Reduced due to uptake of any nitrate by cover crop			

b) MM characterisation and measurement

<table>
<tr><td>What does it mean?</td><td colspan="3">Most farms in Scotland produce spring crops, usually spring barley. Following the previous crop, land may be left until spring before work begins. This can lead to soil erosion on vulnerable sites. A cover crop established in autumn can help to prevent soil erosion. Cover crops include grasses, cereal volunteers and brassica species</td></tr>
<tr><td>Farm input</td><td colspan="3">A range of actions from additional cultivation to encourage ‘greening up’ after harvest through to full establishment of a sown crop.

P and K replaced so less fertiliser needed

Higher fuel usage if straw chopper used

Longer term prevention of soil erosion and winter slumping avoids future costs (loss of nutrients, need to move slump)</td></tr>
<tr><td>Farm output</td><td colspan="3">No effect on output</td></tr>
<tr><td>Farm practice</td><td colspan="3">Possibly some issues later in the season with later harvested crops and cultivating for cover crop</td></tr>
<tr><td rowspan="2">Ecosystem service impacts</td><td>Regulating</td><td>Supporting</td><td>Cultural</td></tr>
<tr><td>Water and soil quality ↑</td><td>Soil formation (reduced erosion) ↑</td><td></td></tr>
<tr><td>Measurement</td><td colspan="3"><u>Primary.</u>
The measurement of uptake of this MM should be by the area under cover crops expressed as a percentage of the land area that is spring-cropped. Ideally this should be estimated annually.
<u>Secondary.</u>
Changes in energy inputs could be inferred from the primary measurement if area-based inputs are used. This would require information on the increase in energy use expected as a result of having cover crops. Change in soil organic carbon loss as a result of growing a cover crop could also be estimated if coefficients are available for SOC loss from bare soil compared to cropped soil.</td></tr>
<tr><td>Building blocks</td><td colspan="3"><u>Primary</u>
[Area with spring crops (new)] [Area with catch crops]
<u>Secondary</u>
[Soil properties: carbon loss (new)]</td></tr>
<tr><td>Data Requirements</td><td colspan="3"><u>Primary</u>
• Area with spring crops (ha) should be collected annually at a farm level and disaggregated by farm type and size.
• Area with catch crops (ha) should be collected every 2-3 years at a farm level and disaggregated by farm type and size.
<u>Secondary</u>
• Coefficients for carbon loss (t/ha) from bare soils and cropped soils are required.</td></tr>
</table>

Existing Data Sources	Primary • Survey of Agricultural Production Methods – asks for the area of sown or cultivated arable land that was covered by a cover crop or an intermediate crop to be ploughed in before spring. Also asks for the area of autumn/ winter crops, so the proportion of wheat in the June Survey that is spring cropped can be estimated. This was designed to be a one-off survey. Would need to be repeated at regular (2-3 yr) intervals to enable monitoring of the uptake of this MM. • IACS – one of the "crops" compatible with the SFPS and that has a code for recording this land-use in the land parcel data is 'Green cover mixtures – land sown with crops normally ploughed in (not intended for harvest). Used to enhance nitrogen content, prevent soil erosion or weeds.' These data are collected annually at field parcel level. • June Agricultural Survey – collects data on crop areas by type, disaggregated by robust farm type and size. These data could be used to estimate the area with spring crops. Secondary • There is an absence of reliable quantitative trend data, which limits the ability to forecast likely future changes in soil organic matter in Scotland[19] • Countryside Survey Chapter 3 in *An Integrated Assessment of Countryside Survey data to investigate Ecosystem Services in Great Britain.* CS Technical Report No. 10/07) did not address changes in specific land use practices such as the growing of cover crops. The study did find that cropland as a category was losing topsoil organic matter. • Other published literature, e.g. Jones and Donnelly, 2004[20]; Jones *et al*., 2006[21]; Guo and Gifford, 2002[22].
Potential New Data Sources	Primary • It is recommended that a regular farm practice survey (such as SAPM) be undertaken to establish the area of land on which cover crops are grown. To be repeated every 2-3 years to capture changes in management. Secondary • Emissions factors for bare versus cropped soils (by research)
Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **green**. This would be improved further if the SAPM

[19] *The State of Scotland's Soil.* Scottish Government (2011)
[20] JONES, M. B., DONNELLY, A.(2004) Carbon sequestration in temperate grassland ecosystems and the influence of management, climate and elevated CO2, *New Phytol*., **164**, 423-439.
[21] JONES, S. K. et al. (2006) Carbon sequestration in a temperate grassland; management and climatic controls, *Soil Use Manage*., **22**, 132-142.
[22] GUO, L. B., GIFFORD, R. M. (2002) Soil carbon stocks and land use change: a meta analysis, *Global Change Biol.* **8**, 345-360.

	were to be repeated. <u>Secondary</u> The potential for existing data sources to successfully capture the major GHG impact (direct CO_2) as a result of implementation of this measure is **red**. At present, the scientific evidence to enable accurate quantification of carbon losses from soil under different vegetation types and land management practices is lacking.

MM11 Crop rotations – particularly including grass

The object of this MM is to reduce soil erosion from bare land and hence reduce losses of soil organic carbon. The main action would be to include temporary grassland in the rotation. By reducing the frequency of cultivation and introducing grass, soil organic matter will increase.

The main barrier to this MM is that some use will be required for the grass and on some farms, this would mean introducing livestock, which may be impractical. As such this MM is most practical in mixed systems, where there is a use for the grassland. The other main barrier would be reduction in the area of potatoes which may be the most profitable crop grown on the farm. In fact, with fewer potatoes being grown, there may be contractual problems with customers.

The GHG inventory will reflect changes to land use in moving from crop land to grassland.

a) MM flow to GHG impact

Baseline Arable land with no grass

↓

MM application Grass included in rotation

↓

Reduced cultivation on land with grass where it is left for up to 5 years

	CO_2		N_2O		CH_4	
GHG impact	Direct	Indirect	Direct	Indirect	Direct	Indirect
	<u>Reduced soil emissions</u>	Fewer cultivations and reduced emissions from soil				

b) MM characterisation and measurement

What does it mean?	Include grass in the rotation – more temporary grass. Improved soil structure. For N fixing crops such as peas and beans, N use will be reduced in that crop and the following crop.		
Farm input	Reduced pesticide usage, reduced fertiliser usage, reduced fuel usage		
Farm output	Reduced arable production, but perhaps increased yields due to improved soils structure and fertility Increased grass production		
Farm practice	Some livestock systems will be limited by housing, transport etc so no need for extra grazing		
Ecosystem	Regulating	Supporting	Cultural

service impacts	Water and soil quality where grass is included ↑	Soil formation ↑ (reduced erosion)	

Measurement	Primary. The measurement of uptake of this MM should be by the area of arable land with grassland in rotation as a percentage of all arable land. This should ideally be updated annually. Secondary. GHG abatement inferred from change in land-use using coefficients for CO_2 emissions from soils under improved grassland and under cultivated land. This would require the use of coefficients for more detailed land-use categories than are reported in the LULUCF sector of the GHG inventory, since 'cropland' in LULUCF covers temporary fallow or grazed land (as part of a crop-pasture rotation).
Building blocks	Primary **Arable area with grass in rotation (new)** **Total arable area** Secondary **Soil properties: carbon loss (new)**
Data Requirements	Primary • The area of arable land in a rotation that includes temporary grassland (ha) ideally should be calculated annually at country level and expressed as a percentage of all arable land. • Total arable land area (ha) Secondary • Coefficients for carbon loss (t/ha) from arable with no grass in rotation and arable with grass in rotation are required.
Existing Data Sources	Primary • The land parcel data included as part of the Integrated Administration and Control System (IACS), which is used to administer land area-based payments in Scotland, could be used to monitor rotations on individual land parcels (which includes grass less than 5 years). At least two years-worth of data would be needed to establish a baseline as an absolute minimum, but this would depend on the frequency of incorporation of grassland into the rotation. There are several years of IACS data available. • June Agricultural Survey – collects data on arable land area, disaggregated by robust farm type and size. Secondary • There is an absence of reliable quantitative trend data, which limits the ability to forecast likely future changes in soil organic matter in Scotland[23] • Countryside Survey Chapter 3 in *An Integrated Assessment of*

[23] *The State of Scotland's Soil.* Scottish Government (2011)

	Countryside Survey data to investigate Ecosystem Services in Great Britain. CS Technical Report No. 10/07) did not address changes in specific land use practices such as the growing of cover crops. The study did find that cropland as a category was losing topsoil organic matter. • Other published literature, e.g. Jones and Donnelly, 2004[24]; Jones *et al*., 2006[25]; Guo and Gifford, 2002[26].
Potential New Data Sources	Primary A question on the incorporation of grassland in an arable rotation could be included in the SAPM if this were to be repeated.
Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **amber**. At present, the land use information collected under IACS is the best source of information on crop rotation, but assumptions would have to be made (e.g. that grassland following arable on a particular parcel would represent grass within a rotation or permanent grass). A decision would also have to be made as to the number of years' worth of data that would be required to be analysed before establishing a baseline. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct CO_2) as a result of implementation of this measure is **red**. At present, the scientific evidence to enable accurate quantification of carbon losses from soil under different vegetation types and land management practices is lacking and in particular evidence with rotational systems.

[24] JONES, M. B., DONNELLY, A.(2004) Carbon sequestration in temperate grassland ecosystems and the influence of management, climate and elevated CO2, *New Phytol*., **164**, 423-439.
[25] JONES, S. K. et al. (2006) Carbon sequestration in a temperate grassland; management and climatic controls, *Soil Use Manage*., **22**, 132-142.
[26] GUO, L. B., GIFFORD, R. M. (2002) Soil carbon stocks and land use change: a meta analysis, *Global Change Biol.* **8**, 345-360.

MM12 Good irrigation practices

Irrigation in Scotland is limited to high value consumer crops e.g. potatoes, root vegetables, green vegetables, fruits. This MM is primarily aimed at avoiding soil erosion and loss of soil carbon when crops are over watered. Most irrigation is carried out on a weekly cycle subject to rainfall. Crops receive too much water usually through a combination of irrigation and unexpected rainfall, or a failure in the system i.e. the irrigator gets stuck, or by poor management. As such this MM is most practical in mixed systems, where there is a use for the grassland.

There should be little in the way of barriers to this MM, since water for irrigation is licensed and limited and buyers of the crop usually work to close specifications.

The energy GHG impact of this MM would be reflected in the inventory. However, any change in the level of soil carbon loss would not show up on the inventory.

a) MM flow to GHG impact

Baseline	Unplanned irrigation system ↓
MM application	Introduce irrigation scheduling Appropriate water usage for situation i.e. soil, season, crop

GHG impact	CO_2		N_2O		CH_4	
Reduced emissions per unit of crop	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Reduced fuel use where less water is used. **SOC losses avoided by reduced erosion**			Reduction in leaching losses		

b) MM characterisation and measurement

<table>
<tr><td>What does it mean?</td><td colspan="3">Use scheduling to reduce water wastage – no change of other inputs</td></tr>
<tr><td>Farm input</td><td colspan="3">More efficient use of inputs – reduced likelihood of overwatering.
Reduced soil erosion risks and therefore reduced future inputs</td></tr>
<tr><td>Farm output</td><td colspan="3">Improved yields and/or quality of irrigated crops – higher value output per area</td></tr>
<tr><td>Farm practice</td><td colspan="3">Scheduling makes good sense, but can be over-ridden by practicalities of moving equipment between fields and the time it takes to get round all fields.</td></tr>
<tr><td rowspan="2">Ecosystem service impacts</td><td>Regulating</td><td>Supporting</td><td>Cultural</td></tr>
<tr><td></td><td>Soil formation ↑ (reduced erosion risk). May reduce water use if all licensed allocation is not used</td><td></td></tr>
<tr><td>Measurement</td><td colspan="3"><u>Primary</u>
The area (ha) of agricultural land irrigated using a scheduled system is required to enable the assessment of uptake of this mitigation measure. Ideally this should be measured every 2-3 years.
<u>Secondary</u>
Direct farm energy use should be estimated approximately every 2-3 years to capture the subsequent decrease in direct energy use due to the introduction of irrigation scheduling. Ideally farm level data should be collected and kept together to help identify a cause-effect relationship. Alternatively, the reduction in energy use as a result of the change in management could be estimated by calculation of the difference in energy requirement between unplanned and scheduled irrigation per hectare.</td></tr>
<tr><td>Building blocks</td><td colspan="3"><u>Primary</u>
Irrigated area
Type of irrigation installed
<u>Secondary</u>
Direct energy use in agriculture
Direct energy use by activity (new)
Farm area</td></tr>
<tr><td>Data Requirements</td><td colspan="3"><u>Primary</u>
• Area (ha) of agricultural land irrigated using a scheduled system, by robust farm type and size.
• Area (ha) of agricultural land irrigated using an unplanned system, by robust farm type and size.
• Area (ha) of agricultural land irrigated using a scheduled irrigation system expressed as a proportion of total area of irrigated agricultural land.</td></tr>
</table>

	Secondary • Total use of fossil fuel energy at farm level, expressed in GJ/ha/yr and disaggregated by fuel type (oil, natural gas, coal, electricity, derived heat) and robust farm type & size. • Farm area (ha) • Coefficients for energy consumption from unplanned and scheduled irrigation per hectare.
Existing Data Sources	Primary • Survey of Agricultural Production Methods – provides areas, methods (surface or sprinkler), source, and volume of water used for irrigation. Time series data on water volume where areas irrigated does not change would indicate the adoption of a scheduling system. This should be done by robust farm type and size to enable statistically robust estimation of mitigation measure uptake. This was designed to be a one-off survey. Would need to be repeated at regular (2-3 yr) intervals to enable monitoring of the uptake of this MM. Secondary • The Department of Energy and Climate Change (DECC) collect statistics on energy consumption by fuel type (including renewables). Publically available statistics are not broken down by both sector (agriculture) and to NUTS 1 (Scotland) at present due the small number of sites. • Farm Accounts Survey – energy consumption could be estimated from expenditure data in the FAS in combination with energy prices. This would mean that the necessary data would be available with annual updates, however the survey is not fully representative of farming in Scotland and the calculations would be based on a number of assumptions. •
Potential New Data Sources	• Record of areas (ha) irrigated by scheduled and unplanned systems to be included in a regular (every 2-3 years) Survey of Agricultural Production Methods.
Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **amber**. The use of scheduled irrigation systems would have to be inferred from existing data on irrigation, which does not explicitly collect information about scheduling. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct CO_2) as a result of implementation of the measure is **red**, because of the inability to capture soil carbon changes. National statistics on energy consumption by fuel type are available, but in order to relate changes in consumption to irrigation system change on farm, energy use data should ideally be collected on these farms. The FAS survey provides on-farm expenditure data for direct energy costs and water usage for irrigation. However, a

	series of time steps

MM13 Creating margins – field margins, field corners, headlands, buffer strips, specific "stewardship" options that affect margins

Introducing field margins, headlands, buffer strips and other non-crop measures will reduce mineral N use on that area of land. Margins can also act as a buffer to surface run off of nitrates from the main body of the field to watercourses. Clearly, this introduces an area of un-cropped land and related loss of food production. Field headlands and corners are generally less productive that the main field area, but this MM can create new headlands where the crop meets the edge of the margin.

Buffers will also likely reduce soil erosion and therefore emissions through oxidation of soil organic matter. Further, soil organic matter will increase in margins due to lack of cultivation

Farmers may be reluctant to take land out of production and this can be a barrier to uptake, although agri-environment schemes offer a range of opportunities to receive payments for loss of income in return for improving biodiversity, water quality, flood mitigation etc. Since creating margins is a voluntary activity, there is a possibility that they could be put back into production subject to market conditions.

The GHG impact of the MM would be mainly be in reduction of mineral N use and the reduction in energy use for cultivations and increased sequestration all of which would be shown in the Agriculture and potentially in the LULUCF chapters of the Inventory.

a) MM flow to GHG impact

Baseline	No field margins ↓
MM application	Create field margins - reduced inputs and increased soil organic matter in uncultivated field margins

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Reduced when no cultivations – energy use and **sequestration**	Reduced when inputs reduced	**Reduced when no cultivation**	Reduced when no fertiliser used		

b) MM characterisation and measurement

<table>
<tr><td>What does it mean?</td><td colspan="3">Take land out of production usually for environmental benefit. Wildlife benefits will vary with prescription for margin</td></tr>
<tr><td>Farm input</td><td colspan="3">Reduced inputs on margins

Cost and time of sowing and mowing</td></tr>
<tr><td>Farm output</td><td colspan="3">RDP payments

Some reduction in production (lost in increased uncultivated are and reduced at new edge), but generally lower yield areas taken and production reduction not always proportionate to area taken out</td></tr>
<tr><td>Farm practice</td><td colspan="3">Often a positive benefit practically by taking out awkward corners, wet areas, strips adjacent to water courses avoids having to worry about Local Environmental Risk Assessment for Pesticides (LERAP)

Strips need proper management to avoid problems of bromes creeping into fields, and to maximise environmental benefits</td></tr>
<tr><td rowspan="2">Ecosystem service impacts</td><td>Regulating</td><td>Supporting</td><td>Cultural</td></tr>
<tr><td>Water quality (↑)
Pollination (↑)
Pest control (↑)</td><td>Soil formation (reduced erosion) (↑)</td><td></td></tr>
<tr><td>Measurement</td><td colspan="3"><u>Primary.</u> The measurement of uptake of this MM should be by the area of uncultivated buffer zones and margins as a percentage of the area of arable land. Ideally this should be measured annually since it is a change that could be readily implemented.
<u>Secondary.</u> Changes in direct N_2O emissions from soils could be inferred from this land-use change if emission factors are used and the area under uncultivated margins etc. is subtracted from the total cultivated area. Ideally this should be calculated annually. Similarly for CO2: if this represents a change from cropland to grassland, then sequestration could be inferred from existing LULUCF emissions factors – though if these areas are only left uncultivated on a short-term basis, then accounting for soil carbon changes will be difficult</td></tr>
<tr><td>Building blocks</td><td colspan="3"><u>Primary</u>
Landscape elements: buffer zones along water | Landscape elements: other uncultivated margins (new) | Total arable area
<u>Secondary</u>
Soil properties: N_2O loss (new) | Soil properties: carbon loss (new)</td></tr>
<tr><td>Data Requirements</td><td colspan="3"><u>Primary</u>
• The area (ha) of buffer zones and other uncultivated margins should be collected annually at farm level.
<u>Secondary</u>
• N_2O loss from cultivated soils can be calculated using IPCC</td></tr>
</table>

	methodology and emission factors. Should be calculated annually • Similarly for CO2: if this represents a change from cropland to grassland, then sequestration could be inferred from existing LULUCF emissions factors although though if these areas are only left uncultivated on a short-term basis, then accounting for soil carbon changes will be difficult
Existing Data Sources	Primary • Scotland RDP (2007-13) monitoring data – the following Land Managers Options are relevant for measuring the area of buffer zones and uncultivated margins at a field parcel level: 'Management of grass margins and beetle banks in arable fields'; 'Management of conservation headlands', as are the following Rural Priorities Options: 'Water margins and enhanced riparian buffer areas'; 'Grass margins and beetle banks'. If implemented, the area of these options is recorded by the land manager in the IACS form per parcel annually. • June Agricultural Survey – collects data on total arable area. Secondary • The Agriculture and LULUCF chapters of the national GHG will include emission factor(s) for cultivated soils.
Potential New Data Sources	None identified
Conclusions	Primary The potential for existing data sources to successfully capture uptake of this measure is **green**, under the assumption that all land managers claim grant aid payment under Land Managers Options for income foregone. Secondary The potential for existing data sources to successfully capture one of the major GHG impacts (direct N_2O emissions) is **green**. This is dependent on the quality of the data collected under the primary measure and the accuracy of the emission factors. The potential for soil carbon depends on whether this measure is likely to lead to longer-term changes which could be considered as a land use change from cropland to grassland (albeit on a small land area), or whether they are likely to be temporary (e.g. like a grass rotation/cover crop) – if the former, then there is potential to capture them using existing emissions factors, but if the latter, then it will be less easy to estimate. Given this uncertainty, overall, we have classified the availability of secondary data as **amber**.

Optimising the application of fertiliser and manures

MM14 Apply fertilisers and manures at recommended rates

In general, farmers apply the relevant amount of inorganic nitrogen to arable crops on the basis of clear recommendations for use and readily quantifiable inputs. Grassland is a little more variable and in combination with the need to dispose of animal manures, it can be a little more difficult to be precise in crop requirements for the potential output. However, in some instances, crop potential is not assessed correctly and there may be too much or indeed too little nitrogen applied. This MM relates to instances where there may be reductions in emissions where nitrogen applied exceeds crop requirements or in contrast, increased emissions where applications are increased to meet a higher crop potential.

One aspect of this MM is that whilst the correct amount of N may be applied overall, it may be that the fertiliser spreader is not being calibrated sufficiently regularly or accurately, which can lead to over or under application in between bouts.

There should be no barriers to this MM, since nitrogen fertiliser is very expensive and farmers are keen to avoid using too much, although this may lead to some under application. Variation in seasonal yields and the impact of unpredictable weather events at key stages of the growing season mean that it is difficult to optimise application rates and farmers tend to over apply as an element of insurance.

Any changes to nitrogen fertiliser use will appear in the Inventory.

a) MM flow to GHG impact

Baseline	Fertiliser applied without planning ↓
MM application	Use of fertiliser planning including organic manures

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Unlikely to lead to fewer passes that would reduce fuel use	May reduce or increase N use depending on practice	**Reduced if currently over applying or increased if currently under fertilising**			

b) MM characterisation and measurement

<table>
<tr><td>What does it mean?</td><td colspan="3">Use RB209 or other system to manage fertiliser rates</td></tr>
<tr><td>Farm input</td><td colspan="3">Optimise inputs – could lead to higher or lower fertiliser use and therefore costs</td></tr>
<tr><td>Farm output</td><td colspan="3">Move toward optimised yield/increased output</td></tr>
<tr><td>Farm practice</td><td colspan="3">Move toward best management practice</td></tr>
<tr><td rowspan="2">Ecosystem service impacts</td><td>Regulating</td><td>Supporting</td><td>Cultural</td></tr>
<tr><td>Air and water quality ↑</td><td></td><td></td></tr>
<tr><td>Measurement</td><td colspan="3"><u>Primary</u>
The measurement of uptake of this MM is the area of agricultural land (ha) subject to fertiliser and manures application rates at recommended rates according to RB209 and PLANET. This also to be expressed as a proportion of the total area of agricultural land (ha) subject to fertiliser and manure application in Scotland. This should be measured annually by crop at a farm level.
<u>Secondary</u>
Changes in the application rates of fertiliser on agricultural land will enable changes in N_2O emissions from agricultural soils to be calculated, based on the assumption that relevant emission factors relating to fertiliser application are available.</td></tr>
<tr><td>Building blocks</td><td colspan="3"><u>Primary</u>
Amount of N applied per crop · Crop area by crop type · Fertilised area per farm
<u>Secondary</u>
Mineral N fertiliser use per farm · Manure N fertiliser use per farm · Soil properties: N_2O loss (new)</td></tr>
<tr><td>Data Requirements</td><td colspan="3"><u>Primary</u>
• Mineral N and manure N application rates (kg/ha) are calculated by dividing the weight of fertiliser applied to each crop by the crop area (ha).
<u>Secondary</u>
• Total amount of applied Nitrogen
• Direct and indirect emission factors (N_2O-N per kg of applied Nitrogen)</td></tr>
<tr><td>Existing Data Sources</td><td colspan="3"><u>Primary</u>
• British Survey of Fertiliser Practice – collects data on mineral and organic fertiliser use per crop in terms of areas and application rates.
• June Agricultural Survey – collects data on crop areas by type, disaggregated by robust farm type and size.
• Scotland RDP (2007-13) monitoring data – the following Rural</td></tr>
</table>

	Priorities Option is relevant for measuring the area of agricultural land fertilised at the recommended rate, at a field parcel level: 'Nutrient Management Plan'. If implemented, the area of this option is recorded by the land manager in the IACS form per parcel annually. • Register of farms using PLANET will provide details of farm areas complying with RB209 standards for fertiliser application. <u>Secondary</u> • Emission factors available in the UK's 2011 GHG inventory submission.
Potential for new data sources	None identified
Conclusions	<u>Primary</u> The potential for existing data sources to successfully capture uptake of the measure is **green**. Data sources capturing fertiliser use provide direct measurement of the uptake of the MM. Uptake of the Rural Priorities Options of the RDP will only provide an indication of fertiliser practice under the grant scheme. <u>Secondary</u> The potential for existing data sources to successfully capture the major GHG impact (direct and indirect N_2O) as a result of implementation of the measure is **amber**. Emission factors for N_2O are, at present, unreliable with a large degree of error. Defra project AC0116 is expected to provide much improved EFs, thus we would expect the measure to be green in the near future.

MM15 Apply fertilisers and manures at recommended times

This MM relates to timing, rather than quantity of fertiliser applied, so any reductions in emissions will be from reduced losses when crop uptake is not optimum. If timings are not correct, nitrogen will be lost via direct and indirect routes at a greater rate than if timing matches crop uptake. For the same application, emissions will be reduced and yields are likely to be improved, resulting in lower emissions per unit of production. There are few barriers to this MM, but in difficult seasons, it may be that wet weather can delay mineral N application timings beyond the optimum and rather than limit crop potential, the normal amount of N may be applied.

It is unlikely that this MM will be captured by the inventory if yield is optimised rather than mineral N reduced.

a) MM flow to GHG impact

Baseline	Fertiliser applied outside recommended times ↓
MM application	Fertiliser applied when the crop can best use it – when crop is actually growing. Note that other nutrients should be balanced for best effect, i.e. lime, which has its own emissions

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
			<u>Reduced due to optimum uptake</u>			

b) MM characterisation and measurement

What does it mean?	Apply according to RB209. Only apply when crop is growing actively Split applications		
Farm input	Reduced N if used more efficiently. Change in other inputs for balance Additional applications would have cost and emissions implications		
Farm output	Same output with reduced N or improved output with same N		
Farm practice	Timing of fertiliser applications targeted at correct time, but variation in fields may mean some are not exact.		
Ecosystem service impacts	Regulating	Supporting	Cultural
	Water quality 🡅		
Measurement	<u>Primary</u> The measurement of uptake of this MM is the area of agricultural land (ha) subject to fertiliser and manures application at		

	recommended times according to RB209 and PLANET. The date of mineral N and manure application should be collected annually, by crop type and area. Inference of the uptake of the MM can then be made by applying a simple yes/no test for the recommendations. This also to be expressed as a proportion of the total area of agricultural land (ha) subject to fertiliser and manure application in Scotland. <u>Secondary</u> Changes in the total volume of fertiliser used on agricultural land as a result of applying fertiliser at the optimum times will enable changes in N_2O emissions from agricultural soils to be calculated, based on the assumption that relevant emission factors relating to fertiliser use are available.
Building blocks	<u>Primary</u> Time of manure N application; Time of mineral N application (new); Crop area by crop type at farm level; Fertilised area per farm <u>Secondary</u> Amount of N applied per crop; Mineral N fertiliser use per farm; Manure N fertiliser use per farm; Soil properties: N_2O loss (new)
Data Requirements	<u>Primary</u> • Mineral N and manure N application timings (month(s) of applications per crop) • Total fertilised area (ha) per farm <u>Secondary</u> • Application rates of Nitrogen (Kg/ha) per crop • Total amount of applied Nitrogen • Direct and indirect emission factors (N_2O-N per kg of applied Nitrogen)
Existing Data Sources	<u>Primary</u> • British Survey of Fertiliser Practice – collects data on mineral and organic fertiliser use by month of application. • June Agricultural Survey – collects data on crop areas by type, disaggregated by robust farm type and size. • Scotland RDP (2007-13) monitoring data – the following Rural Priorities Option is relevant for measuring the area of agricultural land fertilised at the recommended time, at a field parcel level: 'Nutrient Management Plan'. If implemented, the area of these options is recorded by the land manager in the IACS form per parcel annually. • Register of farms using PLANET will provide details of farm areas complying with RB209 standards for fertiliser application. <u>Secondary</u> • British Survey of Fertiliser Practice – collects data on mineral and organic fertiliser use per crop in terms of areas and application rates. • Emission factors available in the UK's 2011 GHG inventory

	submission.
Potential new data sources	None identified
Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **green**. The British Survey of Fertiliser Practice provides direct measurement of the uptake of the MM. Uptake of the Rural Priorities Options of the RDP will only provide an indication of fertiliser practice under the grant scheme. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct and indirect N_2O) as a result of implementation of the measure is **amber**. Difficult to attribute changes in N application rates to changes in application timings. Emission factors for N_2O are, at present, unreliable with a large degree of error. Defra project AC0116 is expected to provide much improved EFs.

MM16 Measure nutrient value of manure and slurry and use first rather than fertiliser

Many farmers use published values for nutrient levels in manures and slurries because they are available and there may be considerable variation in the nutrient content in manures or slurry on their farms, so analysis of a sample only provides an indication of fertiliser value. However, the recent increase in the cost of mineral nitrogen will encourage farmers to value organic manures more and to pay more attention to measuring nutrient content. The correct use of organic manures will increase soil organic matter generally.

Slurries and manures should be sampled and analysed by a commercial laboratory service. This is easily done through many agencies. Alternatively, this may not require measuring manurial values if they are taken from RB209.

This MM is already being taken up and has allowed farmers to reduce significantly their use of mineral nitrogen. The GHG impact of the MM is a reduction in nitrous oxide emissions.

This reduction will show up in the inventory as reduced nitrogen fertiliser use.

a) MM flow to GHG impact

Baseline Manures and slurries not analysed

↓

MM application Analyse manures and slurries to find nutrient content. Apply correct amount of mineral N (potentially more)

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Fewer applications of mineral N	Reduced use of mineral N	**<u>Reduced use of mineral N</u>**			

b) MM characterisation and measurement

What does it mean?	Many farmers do not analyse livestock manures and slurries for nutrient content and risk inaccurate application of fertiliser		
Farm input	May reduce use of mineral fertilisers, cost of testing		
Farm output	Correct use of mineral N to match potential, increase output or increase margin of output.		
Farm practice	Nutrient testing and planning will ensure optimum application		
Ecosystem service impacts	Regulating	Supporting	Cultural
	Water quality ↑		

Measurement	Primary. The uptake of this MM should be measured in two parts. The number of farms testing manures and slurries expressed as a proportion of the total number of farms in Scotland. The area of agricultural land subject to the application of tested manures/slurries in preference to fertiliser, also expressed as a proportion of the total fertilised area. Ideally this should be measured annually at a farm level. Secondary. Changes in the total volume of mineral fertiliser used on agricultural land as a result of analysing manures and slurries will enable changes in N_2O emissions from agricultural soils to be calculated, based on the assumption that relevant emission factors relating to fertiliser use are available.
Building blocks	Primary Number of farms testing manure/ slurry nutrient value (new); Total number of farms; Mineral N fertiliser use per farm; Manure N fertiliser use per farm; Fertilised area per farm; Crop area by crop type at farm level Secondary Amount of N applied per crop; Soil properties: N_2O loss (new)
Data Requirements	Primary a. The number of farms performing manure/slurry nutrient testing in Scotland. b. The total number of farms in Scotland. c. The proportion of farms performing manure/slurry nutrient testing could be calculated by dividing a (above) by b. d. The area of agricultural land (ha) subject to the application of tested manure/slurry in preference to fertiliser, by crop type, could be calculated by summing the fertilised land area for farms which apply manure/slurry before fertiliser. e. The total area of fertilised agricultural land (ha). f. The proportion of agricultural land, by crop type, subject to the application of tested manure/slurry to total fertilised agricultural land could be calculated by dividing d (above) by e. Secondary • Application rates of Nitrogen (Kg/ha) per crop • Total amount of applied Nitrogen • Direct and indirect emission factors (N_2O-N per kg of applied Nitrogen)
Existing Data Sources	Primary • Scotland RDP (2007-13) monitoring data – the following Rural Priorities Option is relevant for measuring the area of agricultural land fertilised at the recommended time, at a field parcel level: 'Nutrient Management Plan'. If implemented, the area of this option is recorded by the land manager in the IACS form per parcel annually.

	• British Survey of Fertiliser Practice – collects data on mineral fertiliser use and organic fertiliser use (numbers and percentages of farms, volumes, areas). • June Agricultural Survey – collects data on crop areas by type. Secondary • British Survey of Fertiliser Practice – collects data on mineral fertiliser use per crop in terms of areas and application rates. • Emission factors available in the UK's 2011 GHG inventory submission.
Potential New Data Sources	It is recommended that a survey of farm practice be undertaken to establish both the number of farms testing manures and slurries, and the number applying manures and slurries preferentially to mineral fertiliser and the subsequent use of mineral N. These questions could be incorporated into SAPM, which already includes a section on manure and slurry application.
Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **amber**. Uptake of the Rural Priorities Option provides measurement of the use of nutrient management plans. However this will only provide indication of manure slurry measurement under the grant scheme. The British Survey of Fertiliser Practice will provide data on changes in the use of organic fertiliser, but no information on the measurement of the nutrient value of manures and slurries. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct and indirect N_2O) as a result of implementation of the measure is **amber**. Difficult to attribute changes in mineral N application rates to uptake of this measure. Emission factors for N_2O are, at present, unreliable with a large degree of error. Defra project AC0116 is expected to provide much improved EFs.

MM17 Separate slurry and fertiliser applications

Crops take up the available nitrogen from both slurry and mineral nitrogen fertilisers. If the amount of available N is above the crop requirement, there is a risk that some will be lost in vaporisation or drainage. The separation of application dates aims to allow uptake of available nitrogen from the first source before the second is applied.

There should be few barriers to this MM since farmers will wish to make the most of any applied nitrogen. However, in wet seasons with limited opportunities to apply fertiliser and slurry to plan, there may be fields where crop requirements are exceeded and the application window is coming to an end so optimum timing is not possible. Farmers will tend to apply the recommendation to avoid potential crop loss.

The GHG impact of this would be a reduction in nitrous oxide emissions where over supply of crop requirement occurred.

Any reduction in mineral N application would be shown in the inventory.

a) MM flow to GHG impact

Baseline	Slurries applied close to mineral fertiliser timing ↓
MM application	Application timing is separated by at least 5 days ↓ Crop uptake of nutrients improved ↓ Crop yield potential to optimum

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
			Reduced losses by volatilisation and leaching			

b) MM characterisation and measurement

What does it mean?	On some farms, application of manures and slurries is not separated from mineral N applications by at least 5 days. This can mean that crop uptake does not match application and nutrients are lost, particularly nitrogen, leading to losses of nitrate and ammonia.		
Farm input	Possible reduction in mineral N		
Farm output	Yield moves toward optimum		
Farm practice	Whilst it may be difficult to avoid in wet times, it is important to separate application to avoid increased emissions and loss of yield		
Ecosystem	Regulating	Supporting	Cultural

service impacts	Water quality		
Measurement	Primary. The number of farms separating the application of manure N and mineral N by 5 days or more is required to measure the uptake of this MM, also presented as a proportion of total farms. The area of agricultural land subject to the recommended application separation, expressed as a proportion of the total fertilised area. Ideally this should be measured annually at a farm level. Secondary. Changes in the quantity of N volatilised and leached as a result of separating the timing of application of organic and mineral N will enable the subsequent changes in N_2O emissions from agricultural soils to be calculated, based on the assumption that relevant emission factors relating to N losses are available. In order to calculate this, the quantity of N applied per crop in a given time period and the crop N requirement in the same time period would be needed to obtain an estimate of the excess N applied.		
Building blocks	Primary Time of manure N application | Time of mineral N application (new) | Total number of farms | Fertilised area per farm Secondary Amount of N applied per crop | Crop area by crop type | Crop N uptake (new)		
Data Requirements	Primary • Date of application of manure N • Date of application of mineral N • The separation (days) between manure N and mineral N is calculated as the difference between the two dates above. • The number of farms with a separation of 5 days or greater between manure N and mineral N application • The total number of farms applying fertiliser • The total fertilised area (ha) per farm Secondary • Application rate of N per crop (kg/ha) for a given period • Area of each crop to which fertiliser is applied (ha) • The N requirement/ uptake of each crop (kg/ha) for a given period		
Existing Data Sources	Primary • Scotland RDP (2007-13) monitoring data – the following Rural Priorities Option is relevant for measuring the number of farms separating manure N and mineral N application by 5 days or more: 'Nutrient Management Plan'. If implemented, the area of this option is recorded by the land manager in the IACS form per parcel annually. Secondary • June Agricultural Survey – collects data on crop areas by type.		

Potential New Data Sources	It is recommended that a survey of farm practice be performed to establish the timing of manure N and mineral N application, and application rates of N over given time periods. This to be stratified by robust farm type and size to be representative. These questions could be incorporated into SAPM, which already includes a section on manure and slurry application.
Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **amber**. Uptake of the Rural Priorities Option provides measurement of the record of fertiliser application timings. However this will only provide indication of fertiliser application timing recording under the grant scheme. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct and indirect N_2O) as a result of implementation of the measure is **amber**. Difficult to attribute changes in volatilisation and leaching to uptake of this measure.

MM18 Low N varieties/ efficient N fix

Crop requirements for nitrogen vary between varieties within a species and from species to species, so within a crop choice, there may be some ability to reduce N use. Triticale is a cereal crop with a much lower N requirement than wheat but can be substituted for it in animal feed and theoretically in ethanol production. However, it has been shown that there are market related barriers to the uptake of triticale. Legumes have no nitrogen requirement and offer an opportunity to reduce N use significantly on both arable farms in the form of peas and beans or on livestock farms as clover.

While the area of peas and beans has declined in recent years, in favour of oilseeds, higher fertiliser prices and new varieties may make these crops more competitive in future. Clover use in grassland has increased to allow livestock farmers to reduce nitrogen use. Previously, barriers existed in the form of increased risk of bloat, but this can be overcome through improved management and new varieties.

The GHG impact will be a significant reduction in N use and emissions which will be borne out in the inventory.

a) MM flow to GHG impact

Baseline	Commercial crops and grass varieties grown ↓					
MM application	Introduce legumes e.g. clover to grass		Introduce low N crops e.g. oats, triticale			
GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Reduced due to fewer applications	Reduced due to reduced amount applied	**<u>Significant reduction due to reduced application</u>**			

b) MM characterisation and measurement

What does it mean?	Growing oats, triticale, peas and beans, lupins		
Farm input	Reductions in mineral N use		
Farm output	Output of oats and triticale is usually expected to be lower than wheat. Peas/beans output lower than alternative break crops Output potentially maintained with triticale or clover		
Farm practice	A tradition of growing oats in Scotland, but the market is already fully supplied so no great scope for expansion Triticale is grown, often as whole crop where maize doesn't grow, but where grown for grain there is not a strong market for it. Beans are not common in Scotland as they are late harvesting. Peas could be an option but can perform very poorly in wet harvest years – common in Scotland. Might be able to increase triticale/lupin mixes for forage – increasing popularity in some parts of SW and Wales		
Ecosystem service impacts	Regulating	Supporting	Cultural
Measurement	<u>Primary</u>. The measurement of implementation in this MM is the change in area of leguminous and low-N crops as a percentage of the total area of arable crops. Also the change in the percentage of clover in permanent grassland. Ideally, this should be measured annually. <u>Secondary</u>. Measurement of the major GHG abatement attributable to the uptake of this measure is through annual calculation of the change in N fertiliser use. For leguminous and low-N crops, this can be inferred from average application rates of fertiliser to these crops if the areas are known. For grassland, this is more difficult since the		

	application rate of fertiliser will depend upon the clover content, and is therefore not a simple area-based calculation.
Building blocks	<u>Primary</u> **Biological N fixation** · **Percentage of clover in grass (new)** · **Crop area by crop type** · **Total arable area** · **Total grassland area** · **Farm typology** <u>Secondary</u> **Mineral N fertiliser use per farm** · **Amount of N applied per crop** · **Fertilised area per farm**
Data Requirements	<u>Primary</u> • Areas of leguminous and low-N crops (ha) should be collected at the farm level and disaggregated by robust farm type and size. • An estimate of the percentage of clover in grassland is required, ideally at farm level and disaggregated by robust farm type and size. • Area of arable land and grassland for use as denominators. <u>Secondary</u> • Mineral N fertiliser use (Kg/ha/yr) is calculated by multiplying the area of each crop type per farm by the application rate of N fertiliser for that crop, then dividing by the total fertilised area. Ideally, data should be collected annually at farm level and disaggregated by robust farm type and size. • For grassland, coefficients for fertiliser use dependent on clover content are required.
Existing Data Sources	<u>Primary</u> • June Agricultural Survey – collects data on crop areas by type, disaggregated by robust farm type and size. Relevant crops in the JAS for monitoring the implementation of this MM are: oats; triticale; peas for combining; beans for combining; lupins. • Grassland seed sales – to estimate clover content in grass seed mixtures. <u>Secondary</u> • British Survey of Fertiliser Practice – collects data on mineral fertiliser use per crop in terms of areas and application rates. • Data from published literature that enable calculation of expected reduction in mineral N application as a result of an increase in clover content of grassland. For example, in Defra's Fertiliser Manual (RB209)[27] recommendations.
Potential New Data Sources	<u>Primary</u> • A question in the June Agricultural Survey asking for an estimate of the average clover content of any grassland.

[27] Anon. (2010). *Fertiliser Manual (RB209),* Defra, 8th edition. The Stationery Office, London.

	<u>Secondary</u> • A question in the British Survey of Fertiliser Practice on fertiliser use on grassland dependent on the clover content (if data not already collected).
Conclusions	<u>Primary</u> The potential for existing data sources to successfully capture uptake of the measure is **amber**. Sufficient data area available on areas of leguminous and low-N crops, but data on clover content of grassland is more difficult to come by. <u>Secondary</u> The potential for existing data sources to successfully capture the major GHG impact (N_2O) as a result of implementation of this measure is **amber**. Data are available to enable the calculation of changes in fertiliser use with an increased area of leguminous or low-N crops, but it is more difficult to estimate change in fertiliser use on grassland with increased clover content.

MM19 Composts and straw based manures in preference to slurry

The object of this MM is for farmers to use composts on crops or on dairy and livestock farms to use straw as bedding to produce farm yard manure (FYM) instead of slurry and hence potentially to reduce emissions associated with slurry production. In FYM, readily available nitrogen is more likely to be broken down to nitrogen gas than nitrous oxide. However, to change over to FYM based systems, those farms on slurry systems would need to make significant capital investments in livestock buildings which require more space per animal.

Composts tend to be low in N content although they will add to the organic manure in a soil. FYM generally contains less N than slurry, so in both cases, increased use of mineral N may result.

The main GHG impact would be to reduce nitrous oxide emissions from slurry, although the increased use of mineral N and associated emissions may negate this.

Use of compost only changes emissions on the field in question, it does not change production of slurry.

In relation to method of spreading, manure & compost would be incorporated, whereas slurry may be spread by broadcast spreader creating greater emissions from slurry – may be as ammonia leading to secondary losses of N_2O. CH_4 losses from manures may be lower than slurries.

We have assumed this MM only applied to arable farms with no livestock, where all organic fertiliser is imported because the MM would already be in place on mixed farms. On dairy farms with arable land, slurry systems are often the most efficient way of dealing with excreta and a change to straw based manures would mean high capital expenditure.

Inventory issues: where excreta is in the form of FYM rather than slurry, changes will appear on agriculture inventory. Uncertain mineral N effect

a) MM flow to GHG impact

Baseline	Slurry imported to arable farm ↓	
MM application	Use compost	Use straw based manure Restricted timing of application, limited crop range

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
		Potential to increase if composts are low in N and additional mineral N is required	**<u>Potentially reduced in manure compared with slurry</u>**		Potentially reduced in manure compared with slurry	

b) MM characterisation and measurement

What does it mean?	Slurry produces more GHG than manure and composts. Increase in soil organic matter?		
Farm input	Uncertain due to tradeoffs between appropriate nutrients in compost/straw manure, slurry and mineral N		
Farm output	Output unchanged if optimum nutrient balance maintained		
Farm practice	Composts are more likely to be from green manures which are unable to supply the crop requirement for available N and generally need supplementation by mineral N. When using FYM, crop available nitrogen is limited and generally requires supplementation with mineral N (see RB209 recommendations)		
Ecosystem service impacts	Regulating	Supporting	Cultural
Measurement	<u>Primary</u>. The measurement of uptake of this MM would be by the increase in the proportion of compost and FYM (by weight) in the organic fertiliser imported to arable farms. This should be estimated every 2-3 years. <u>Secondary</u>. An increase in indirect energy use may result due to the lower N content of composts and FYM as compared to slurry resulting in the increased manufacture of mineral N fertiliser to make up the difference. Thus the measurement of the major GHG impact would be through estimation of the increased amount of mineral N fertiliser that would be used as a result of uptake of this measure.		
Building blocks	<u>Primary</u> **Organic fertiliser type (new)** **Farm typology**		

	Secondary **N in imported manure** · **N in imported compost (new)** · **N in imported slurry (new)** · **Indirect energy use in agriculture**
Data Requirements	Primary • The quantity of imported organic fertiliser (t /yr) that is in the form of slurry, FYM and compost expressed as a proportion of the total organic fertiliser used on arable farms. Secondary • Indirect energy use (GJ/farm/yr) is related to the production of farm inputs such as fertilisers and purchased feed and should be calculated at farm level using input building blocks and Life Cycle Analysis.
Existing Data Sources	Primary • British Survey of Fertiliser Practice – collects statistics on the numbers and percentage of farms importing each type of organic manure (cattle FYM, cattle slurry, pig FYM, pig slurry, layer/hen manure, broiler/turkey litter, other FYM, other – where other would include but not be limited to composts) and the quantity imported (t). Also reports the percentage of sown area where organic manure is applied receiving each organic manure type. Note that the underlying sample design is constructed to measure manufactured fertiliser usage and may not wholly represent the population of farmers using organic manures. • Survey of Agricultural Production Methods – questions are asked regarding manure and slurry application: 'On what area of land was solid manure applied..?'; 'Of this, on what area was solid manure ploughed in within 4 hours of application?'; 'On what area of land was slurry applied..'; 'Of this, on what area was slurry injected into the soil or ploughed in within 4 hours of application?' This is a one-off survey at present. • June Agricultural Survey – number of arable farms Secondary • Typical values for nutrient contents of organic manure types (including composted green manure) are provided in the 2010 report of the British Survey of Fertiliser Practice (Table D2.2). Average manure application rates to winter sown, spring sown crops and grassland by manure type are also provided (Table D2.3).
Potential New Data Sources	None identified – other than to include composted green manure as a specific category in the BSFP (this may be collected as such already).
Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **green**. Much of what is needed is collected as part of the BSFP, although it may not be a fully representative sample. Could be compared to results of SAPM.

	<u>Secondary</u> The potential for existing data sources to successfully capture the major GHG impact (indirect CO_2) as a result of implementation of this measure is **amber**. The necessary coefficients are available, as are the primary activity data, however there is a large assumption made in that farmers will supplement their organic manure application with mineral fertiliser as a result of this measure.

MM20 Methods of slurry application

Until recently, many farms used a vacuum tanker to broadcast slurry on to fields. Slurry tankers have been increasing in size and cost and now, many farmers use contractors to spread their slurry in order to avoid the capital investment and the labour required to carry out the work. In addition, new techniques to spread slurry have been developed including dribble bars and trailing shoe machines. These place slurry close to the ground and reduce the risk of contamination when making silage or grazing. Application can be by using a tanker with the appropriate spreading machine or by use of an umbilical system, which trails a pipe from a tanker, avoiding potential soil compaction.

A key issue is to match the machinery to the task and to complete the work when conditions are suitable. Where this is not the case, it can create soil damage which leads to nitrate run-off and soil erosion and loss of soil organic matter.

Allows rapid incorporation of N. This increases the availability of N in the soil and mineral N use should be reduced to balance this. Reduction in ammonia from MANNER NPK: Trailing hose -30%, Shallow injection -70%, Trailing shoe short grass aftermaths -30%, long -60%.

The main GHG impact is reduced indirect N_2O from ammonia. Ammonia is calculated on total amount applied, not per ha. Improved application through trailing shoe etc. may increase carbon dioxide emissions.
Inventory issues: changes may be shown on agriculture inventory via reduced mineral N

a) MM flow to GHG impact

Baseline	Current application by broadcast tanker ↓
MM application	Use trailing shoe, trailing hose or injection ↓
	Likely to be contract operation unless large farm ↓
	Changes to farm investment – if contract operation, will go to all trading expenses

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Change in fuel use due to application method		**<u>Reduced secondary losses due to ammonia, but increases due to increased nitrate leaching</u>**			

b) MM characterisation and measurement

<table>
<tr><td>What does it mean?</td><td colspan="3">Changing from application of slurry with a vacuum tanker and broadcast nozzle to a more accurate method i.e. trailing hose, trailing show or injection.</td></tr>
<tr><td>Farm input</td><td colspan="3">May reduce mineral N input</td></tr>
<tr><td>Farm output</td><td colspan="3">No change if crop requirement is met</td></tr>
<tr><td>Farm practice</td><td colspan="3">Small and medium farms may move to a contractor operation to avoid the capital investment of the larger equipment as well as the labour requirement of the operation.

Where contractors used, expense becomes a trading expense and avoids loans for capital equipment. Contractor costs are generally below the unit costs to all but large farms</td></tr>
<tr><td rowspan="2">Ecosystem service impacts</td><td>Regulating</td><td>Supporting</td><td>Cultural</td></tr>
<tr><td>Climate regulation</td><td>Nutrient cycling</td><td></td></tr>
<tr><td>Measurement</td><td colspan="3"><u>Primary</u>.
The quantity of slurry and manure spread by these methods as a proportion of the total is required to measure the uptake of this MM. Ideally this should be measured every 2-3 years.
<u>Secondary</u>
The change in the major GHG impact as a result of implementation of this MM should be measured by applying ammonia emission factors from surface spread vs. new techniques to the quantity of manure/ slurry applied by each.</td></tr>
<tr><td>Building blocks</td><td colspan="3"><u>Primary</u>
Manure application technique | Fertilised area per farm
<u>Secondary</u>
Amount of N applied per crop | Crop area by crop type | Ammonium-N emission factors by slurry application method</td></tr>
<tr><td>Data Requirements</td><td colspan="3"><u>Primary</u>
• Area of agricultural land (ha) which is subjected to slurry application, by robust farm type and size.
• Area of agricultural land (ha) which is subjected to slurry application by trailing hose, trailing shoe, or injection, by robust farm type and size.
<u>Secondary</u>
• Application rate of N per crop for each application method.
• Area of crop N has been applied to (ha).
• The total amount of N applied using each method, which can be calculated by multiplying the application rate by the crop area
• Emission factors for Ammonium-N loss from the different application methods.</td></tr>
<tr><td>Existing Data</td><td colspan="3"><u>Primary</u></td></tr>
</table>

Sources	• British Survey of Fertiliser Practice – collects data on the number and percentage of farms using each type of slurry application method (broadcast, band spread, shallow injection, deep injection, rain gun, rotating boom). Scottish data would have to be requested (only UK published at present for organic fertilisers). There are, however sampling issues due to the fact that the survey is based on mineral N fertilisers and may not be representative. Secondary • June Agricultural Survey – collects data on crop areas by type. • MANNER NPK – to estimate % reductions in usage based on application method
Potential New Data Sources	Primary It is recommended that a survey of farm practice be performed to establish the method of manure N and mineral N application, and application rates of N over given time periods. This to be stratified by robust farm type and size to be representative. Could be performed every 2-3 years to capture the impact of uptake on the major GHG, and expanded to capture all forms of slurry application.
Conclusion	Primary The potential for existing data sources to successfully capture uptake of this measure is **green**. The SAPM gives areas of land slurry has been applied to and the British Survey of Fertiliser Practice provides the necessary information on the percentage split between application techniques to enable the monitoring of changes in uptake of this measure. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct and indirect N_20) as a result of implementation of this measure is **amber**. Ammonia losses arising from use of the different application methods could be calculated through the use of ammonia emission factors for each application method, however these are not available as standard factors in the inventory and should be sourced from scientific literature. An assumption must be made as to the % reduction in total N applied as a result of a change in practice...

Optimising livestock management and storage of waste

MM21 Cover stored slurry and manure

Covering slurry stores can reduce ammonia emissions and hence secondary nitrous oxide emissions. Covers are unlikely to have a significant effect on methane production. It is difficult to retro fit slurry store covers. They may be useful if slurry store is marginally too small for NVZ so avoids investment in new store.

Manure storage is a different matter, when in many cases, when livestock buildings are emptied, the manure is left until required for spreading in the field and covering is not an option. Some FYM is removed from buildings and stacked in field stores where it may be possible to apply a cover. In FYM, readily available nitrogen in the form of ammonia is retained, but is as likely to be lost at spreading unless rapidly incorporated into the soil. Covered FYM stores mean that the FYM is wetter when spreading occurs, which can make it difficult to work with.

In terms of efficacy, a record would be required of whether a cover is in place and if it is in tact.

These processes are not straightforward and are a balance of nitrification and de-nitrification.

The main GHG impact is to reduce losses of ammonia and secondary nitrous oxide emissions.

Inventory issues: no changes will appear on agriculture inventory. There is no differentiation between waste handling systems at this level of detail

a) MM flow to GHG impact

Baseline	Slurry and manure uncovered ↓ Cover manure stored in open heaps with plastic sheet	 Install slurry store cover

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
				Reduction due to less ammonia lost	Possible reduction due to fewer losses.	

b) MM characterisation and measurement

<table>
<tr><td>What does it mean?</td><td colspan="3">Much of the manure produced by livestock in housed accommodation is left there until it can be applied to the land. Some is stored in open field heaps and may benefit from being sheeted over to reduce GHG emissions.

Slurry stores: main effects are to reduce entry of rainfall and ammonia losses. With regard to GHGs, ammonia losses are reduced by preventing surface stripping and methane losses may be reduced due to maintaining partial pressures, although methane production will continue due to bacterial action. Covers do not need to be gas tight, but reasonably close fitting, being a tented structure supported by a steel pole in the centre of the store and around the circumference of the store. This is often more useful in keeping out rainfall.</td></tr>
<tr><td>Farm input</td><td colspan="3">Increase capacity of store and may reduce mineral N input and save costs
Material and labour costs – plastic sheets
Capital expenditure and professional installation – store covers</td></tr>
<tr><td>Farm output</td><td colspan="3">No effect on output</td></tr>
<tr><td>Farm practice</td><td colspan="3">Many farmers do not like covering slurry stores because the result is a thicker slurry which is difficult to handle</td></tr>
<tr><td rowspan="2">Ecosystem service impacts</td><td>Regulating</td><td>Supporting</td><td>Cultural</td></tr>
<tr><td>Air quality ↑</td><td></td><td></td></tr>
<tr><td>Measurement</td><td colspan="3"><u>Primary</u>.
The quantity of slurry and manure stored in covered stores as a proportion of the total quantity of slurry and manure is required to measure the uptake of this MM. Ideally this should be measured every 2-3 years.
<u>Secondary</u>
The change in the major GHG impact as a result of implementation of this MM should be measured by applying ammonia emission factors from covered vs. uncovered stores to the quantity of manure/ slurry stored in each type.</td></tr>
<tr><td>Building blocks</td><td colspan="3"><u>Primary</u>
Manure stored in covered tanks | Manure stored in lagoons | Manure stored in manure heaps | Manure stored in underfloor pits
<u>Secondary</u>
Ammonium-N emission factors from manure by storage type (new) | Ammonium-N emission factors from slurry by storage type (new)</td></tr>
<tr><td>Data Requirements</td><td colspan="3"><u>Primary</u>
• The number of farms storing manure/slurry, by robust farm type and size
• The number of farms storing manure/slurry in covered stores, by robust farm type and size</td></tr>
</table>

	• The quantity (l or kg) of slurry and manure stored, by robust farm type and size Secondary • Emission factors for Ammonium-N from stored slurry and manure by covered and uncovered stores
Existing Data Sources	Primary • Survey of Agricultural Production Methods – asks for the presence of manure/slurry storage, and whether or not it is covered. This was designed to be a one-off survey. • Scotland RDP (2007-13) monitoring data – the following Rural Priorities Option is relevant: 'Manure/Slurry Storage'. Investment under this Option may include installation of covers for slurry storage facilities and middens. Data on the number of farms taking up this option should be available. Secondary • Emission factors for ammonia from stored slurry and manure are available in the scientific literature and from the annual UK ammonia inventory.
Potential New Data Sources	It is recommended that the SAPM be repeated every 2-3 years to monitor uptake of this MM.
Conclusions	Primary The potential for existing data sources to successfully capture uptake of this measure is **amber**. The one-off SAPM gives the number of farms storing slurry and the number of farms storing slurry in covered stores. This survey would need to be repeated to capture trends in uptake of the measure. This could be compared to the uptake of the Rural Priorities Option of the RDP. Secondary The potential for existing data sources to successfully capture the major GHG impact (indirect N_2O) as a result of implementation of this measure is **amber**. This relies on the frequency of collection of the related activity data.

MM22 Aerate stored slurry and manure

The object of aeration is to increase nitrification of ammonium to nitrate which is then reduced to nitrogen gas form hence reducing ammonia and nitrous oxide emissions. In slurry, this is achieved using a large rotating mixer. It is unlikely to affect the production of methane, which is a function of bacterial activity and temperature.

In FYM, where it is left in place, it is likely to be compacted with a risk of ammonia and methane losses. Where the FYM is removed and field stacked, it is possible to compost it, resulting in aerobic conditions and reduced ammonia and methane emissions.

The main GHG impacts will be potential reductions in secondary nitrous oxide losses, but there will be some increased CO_2 emissions from slurry stirrer and the FYM composting operation.

Inventory issues: unlikely to be significant increase in energy use to show on inventory. Change in ammonia will not be recorded in inventory

a) MM flow to GHG impact

Baseline	Slurry store not aerated
	↓
MM application	Install slurry store stirrer

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Increase due to energy use in stirring			**Reduced losses of ammonia**		

b) MM characterisation and measurement

What does it mean?	Purchase of a slurry stirrer, an electrically driven machine to avoid crusting of slurry and allow oxidation to increase the rate of N_2 production		
Farm input	No effect on input Capital expense for stirrer plus running costs		
Farm output	No effect on output		
Farm practice	Stirrers generally purchased for ease of operation when slurry stores emptied		
Ecosystem service impacts	Regulating	Supporting	Cultural
	Air quality ↑		

Measurement	Primary The number of farms storing manure/slurry in aerated stores (stirred), expressed as a proportion of all farms storing manure/slurry, is required for the measurement of uptake of this MM. Secondary The change in the major GHG impact as a result of implementation of this MM should be measured by applying ammonia emission factors from aerated vs. un-aerated stores to the quantity of slurry stored in each type.
Building blocks	Primary Slurry stored in un-aerated store (new) / Slurry stored in aerated store (new) Secondary Ammonium-N emission factors from slurry by storage type (new)
Data Requirement	Primary • The number of farms storing slurry, by robust farm type and size • The number of farms storing slurry in aerated stores, by robust farm type and size • The quantity (l) of slurry stored, by robust farm type and size Secondary Emission factors for Ammonium-N from stored slurry and manure by aerated and un-aerated stores
Existing Data Sources	Secondary • Emission factors for ammonia from stored slurry are available in the scientific literature and from the annual UK ammonia inventory. We have not found different EFs for aerated v non-aerated stores
Potential New Data Sources	It is recommended that the aeration of manure/slurry stores be included in the Survey of Agricultural Production Methods or a similar survey of farm practice. Would need to be repeated at regular (2-3 yr) intervals to enable monitoring of the uptake of this MM.
Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **red**. There is no public domain data source that records the proportion of slurry stores that are aerated. Secondary The potential for existing data sources to successfully capture the major GHG impact (indirect N_2O) as a result of implementation of this measure is **red**. Without the necessary activity data, this cannot be calculated.

MM23 Draw up and regularly review animal health plans

This MM is aimed at avoiding lost production from animals underperforming due to health issues. Health issues can arise from a range of management issues from poor housing and provision of clean drinking water to parasite and disease management

A healthy animal will perform at optimum level given correct management. Improved health leads to lower emissions per unit of production.

The evidence would be to draw up an animal health plan and follow it as in a crop nutrient plan.

This aligns with animal welfare measures in Scottish RDP

AHVLA (Animal Health and Veterinary Laboratories Agency, part of Defra) is about to undertake a project to estimate a GHG MACC for animal health improvements for a list of 10 or so diseases and conditions

The main GHG impacts will be due to animals for meat reaching slaughter weight at correct time, saving methane emissions. There will be a reduction in the number of dairy cows culled due to infertility, foot and udder problems, saves GHGs (methane) over their lifetime.

Inventory issues: This could lead to fewer head and if so, will be reflected in agriculture inventory

a) MM flow to GHG impact

Baseline No animal health plans

↓

MM application Draw up animal health plan

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Stock performing to target will result in reduced emissions per unit of production				**Healthy animals' performance optimised**	

b) MM characterisation and measurement

What does it mean?	Correct animal health planning will save losses of performance as well as total loss of some animals
Farm input	May increase use of medicines, but avoids emergency uses where unplanned events occur
Farm output	Improved livestock performance

<table>
<tr><td>Farm practice</td><td colspan="3">Reduced performance means relatively greater emissions per head and loss means a complete waste of emissions for no production. Consequential changes mean lower breeding rates and higher relative emissions per unit of production along with further emissions associated with pharmaceutical inputs and possibly increased bedding.</td></tr>
<tr><td rowspan="2">Ecosystem service impacts</td><td>Regulating</td><td>Supporting</td><td>Cultural</td></tr>
<tr><td>Regulation of water, air and soil quality ↑</td><td>NA</td><td>NA</td></tr>
<tr><td>Measurement</td><td colspan="3"><u>Primary</u>. Annual data on the uptake of animal health plans should be used to monitor the implementation of this measure.
<u>Secondary</u>. Uptake of the health plans could then be related to changes in production. Productivity can be measured as output per head of livestock. Ideally this needs to be measured on farms that have taken up health plans and compared to productivity on similar farms that have not.</td></tr>
<tr><td>Building blocks</td><td colspan="3"><u>Primary</u>
Animal health plans (new)
<u>Secondary</u>
Livestock number by species | Meat production by species | Egg production by species
Milk production by species | Offspring production by species (new) | Barren females by species (new)</td></tr>
<tr><td>Data Requirements</td><td colspan="3"><u>Primary</u>
• Number of animal health plans drawn up per annum.
<u>Secondary</u>
• Number of livestock of each type (e.g. dairy, beef, sheep) to be collected at a farm level.
• Meat, egg and milk production (Kg, #, L per head) to be collected at a farm level.
• Offspring production can be measured as the number of offspring weaned, sold or retained as a percentage of the number of females mated per livestock type per farm. Number of barren females counted per livestock type per farm.</td></tr>
<tr><td>Existing Data Sources</td><td colspan="3"><u>Primary</u>
The Animal Welfare Management (AWM) Programme is one of the options under the Land Managers Options Scheme in the RDP (2007-13). The aim is to support livestock producers (cattle, sheep or goats) to adopt and continually improve high standards of animal welfare over a 5-year programme. The programme must include;
• An animal welfare review to include an assessment by a vet of;
  ○ Good feeding
  ○ Good housing/ environment
  ○ Good health
  ○ Appropriate behaviour
• Animal welfare monitoring and benchmarking, which includes recording of breeding and welfare measures.</td></tr>
</table>

	• An animal welfare management plan based on the above
	• A minimum of 3 specific actions to improve welfare, to be chosen from the following list;
	  ○ Improvement of biosecurity
	  ○ Reducing mutilations in sheep
	  ○ Maintaining bodily condition
	  ○ Preventing lameness
	  ○ Mastitis control
	  ○ Control and prevention of diarrhoea and pneumonia
	  ○ Liver fluke control
	  ○ Johne's disease control
	  ○ Control of bovine viral diarrhoea (BVD)
	  ○ Sheep scab control
	<u>Secondary</u>
	• June Agricultural Survey – collects data on livestock numbers by type per holding. This includes calves, lambs, piglets etc.
	• Scottish Agriculture output, input and income statistics – presents information on outputs (e.g. finished livestock, livestock products), both in terms of monetary value and 000 tonnes carcase weight, million litres of milk, millions of eggs.
	• Farm Accounts Survey – collects information on the average value of agricultural outputs such as meat, eggs and milk by farm type and size. These could be converted to weights or volumes based on unit market price.

Potential for new data sources	<u>Secondary</u> Ideally a survey of farmers taking up animal health plans, matched to a control sample of farmers that haven't, should be carried out to attempt to quantify changes in production as a result of implementing these plans. The available production data look at trends, but there may be many factors contributing to increases in production, therefore they cannot be directly attributed to this measure unless measured as part of a matched case-control study.
Conclusions	<u>Primary</u> The potential for existing data sources to successfully capture uptake of the measure is **green**, under the assumption that the majority of farmers drawing up animal health plans will do so with support from the RDP. <u>Secondary</u> The potential for existing data sources to successfully capture the major GHG impact (direct CH_4) as a result of implementation of this measure is **amber**. National statistics on production are available, but in order to relate changes in production to animal health plans, production data should ideally be collected on these farms. Additional data may be available when the animal health GHG MACC is completed.

MM24 Promote efficiency with regards to breeding

The object of this MM is to achieve optimum output from breeding stock in terms of number and quality of offspring. This would mean that where performance is improved, emissions per unit of production are reduced.

There may be data issues on breeds and breeding stock.

EBV Quality meat Scotland monitor number of tups and this can be used to inform management decisions.

The main GHG impact would be to reduce emissions per unit of output.

Inventory issues: improvements to output that lead to reduced numbers of stock would show up on the agriculture inventory.

a) MM flow to GHG impact

Baseline	Breeding policy aimed at cost not quality ↓
MM application	Use high quality breeding stock

	CO_2		N_2O		CH_4	
GHG impact	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Stock performing to target will result in reduced emissions per unit of production				**Reduced emissions over lifetime and per unit of output**	

b) MM characterisation and measurement

What does it mean?	Many farmers breed on price of sire either live or AI, or custom, not quality. There is a need to use Estimated Breeding Value and Profitable Lifetime Index. Improve fertility, improve numbers of stock reared, improve quality of stock reared and value. Purchase better breeding stock: use genetic indices to identify superior stock. Low numbers reared mean relatively high emissions per head of breeding stock. Will vary in sheep in particular due to breed and situation i.e. hills v lowland.
Farm input	Higher input costs - more expensive to use selected sires than own or local sire
Farm output	Improved yields
Farm practice	May involve changes from renting a bull to use of AI and the need

	to improve heat detection		
Ecosystem service impacts	Regulating	Supporting	Cultural
	Regulation of water, air and soil quality	NA	NA
Measurement	<u>Primary</u>. The monitoring of the implementation of this MM will be the change in quality of breeding stock on a farm level, ideally based on measures such as Estimated Breeding Value and Profitable Lifetime Index, but could also be based on expenditure on breeding stock. <u>Secondary.</u> Changes in breeding stock could then be related to changes in production and fecundity. Productivity can be measured as output per head of livestock. Ideally this needs to be measured on farms that have improved their breeding stock and compared to productivity on similar farms that have not.		
Building blocks	<u>Primary</u> Quality of breeding stock (new) Farm typology <u>Secondary</u> Livestock number by species Meat production by species Egg production by species Milk production by species Offspring production by species (new) Barren females by species (new)		
Data Requirements	<u>Primary</u> • The quality of breeding stock at farm level (e.g. average EBV; £/head), ideally collected every 2-3 years and disaggregated by farm type and size. <u>Secondary</u> • Number of livestock of each type (e.g. dairy, beef, sheep) to be collected at a farm level. • Meat, egg and milk production (Kg, #, L per head) to be collected at a farm level. • Offspring production can be measured as the number of offspring weaned, sold or retained as a percentage of the number of females mated per livestock type per farm. Number of barren females counted per livestock type per farm.		
Existing Data Sources	<u>Primary</u> • Farm Accounts Survey – estimates average inputs by farm type and size for a number of categories including 'Other livestock expenses', but not specifically purchase of breeding stock. <u>Secondary</u> • June Agricultural Survey – collects data on livestock numbers by type per holding. This includes calves, lambs, piglets etc. • Scottish Agriculture output, input and income statistics –		

	presents information on outputs (e.g. finished livestock, livestock products), both in terms of monetary value and 000 tonnes carcase weight, million litres of milk, millions of eggs. • Farm Accounts Survey – collects information on the average value of agricultural outputs such as meat, eggs and milk by farm type and size. These could be converted to weights or volumes based on unit market price.
Potential for new data sources	Primary • A survey of livestock farms every 2-3 years to find out their breeding policy would be beneficial. Could also ask questions on production so that this could be directly related to changes in breeding policy. Should be stratified by robust farm type and size.
Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **red**. There is little information in the public domain with regards the quality of breeding stock. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct CH_4) is **red**. Without the necessary data on changes in the quality of breeding stock, it is not possible to attribute any change in GHG emission to this measure.

MM25 Promote efficiency of food conversion

This MM is a combination of 24 and 26, but covers the quality of implementation of selection of better performing animals, feeding and avoidance of waste in feed, both forage and purchased concentrates.

Records required for production efficiency are already carried out by many livestock and dairy farmers. This could be added to by slaughterhouse data – deadweight fat class 3 or above

The main GHG impact would be reduced methane emissions due to increased efficiency.

Inventory issues: unlikely to show up on agricultural inventory unless livestock numbers reduced

a) MM flow to GHG impact

Baseline	Poor implementation of breeding and feeding policy ↓
MM application	Plan feed on quality ↓
GHG impact	↓
Economic impact	Input higher cost of quality feed. Output - improved performance

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Stock performing to target will result in reduced emissions				<u>**Reduced emissions over lifetime and per unit of output**</u>	

b) MM characterisation and measurement

What does it mean?	Identify superior animals for feeding programme, formulate diets to maximise growth, slaughter animals at younger ages when FCE at it's highest. Minimise waste, make high quality forage – use improved plant varieties.
Farm input	Higher feed costs
Farm output	Improved performance – weight gain, yield
Farm practice	Best management practice: A more professional approach required

<table>
<tr><td rowspan="2">Ecosystem service impacts</td><td>Regulating</td><td>Supporting</td><td>Cultural</td></tr>
<tr><td>Regulation of water, air and soil quality ↑</td><td></td><td></td></tr>
<tr><td>Measurement</td><td colspan="3">Primary. Measurement of the implementation of this MM would require quantification in changes in feed quality, which should be measured in terms of its nutrient content.
Secondary. The increase in production as a result of improved feed quality would require farm records on livestock diet and production efficiency. The challenge here is to keep the farm level records on feed quality and production together to demonstrate a cause and effect relationship.</td></tr>
<tr><td>Building blocks</td><td colspan="3">Primary
[Feed intake] [Nutrient composition of feed (new)] [Livestock number by species]
Secondary
[Meat production by species] [Egg production by species] [Milk production by species]</td></tr>
<tr><td>Data Requirements</td><td colspan="3">Primary
• Feed intake (calories per head) to be collected per livestock type and age at a farm level.
• Nutrient composition of feed (e.g. % protein content, % carbohydrate, % fibre) to be collected per livestock type at a farm level.
• Number of livestock of each type (e.g. dairy, beef, sheep) to be collected at a farm level.
Secondary
• Meat, egg and milk production (Kg, #, L per head) to be collected at a farm level.</td></tr>
<tr><td>Existing Data Sources</td><td colspan="3">Primary
• June Agricultural Survey – collects data on livestock numbers by type per holding.
• Scottish Agriculture output, input and income statistics – presents information on inputs (e.g. feedstuffs, veterinary expenses and medicines) in £M and volume indices BUT no related data on feed quality. Quality could be inferred from average price per head by farm type and size.
Secondary
• Farm Accounts Survey – collects information on the average value of agricultural outputs such as meat, eggs and milk by farm type and size. These could be converted to weights or volumes based on unit market price.
• Scottish Agriculture output, input and income statistics – presents information on outputs (e.g. finished livestock, livestock products), both in terms of monetary value and 000 tonnes carcase weight, million litres of milk, millions of eggs.</td></tr>
</table>

	• Slaughterhouse data – deadweight fat class. Needs to be linked back to farm-level data on feed quality via animal ID.
Potential for new data sources	Primary A survey of livestock farms every 2-3 years asking questions on their feeding plan would be beneficial. Could also ask questions on production so that this could be directly related to changes in feed quality. Should be stratified by robust farm type and size.
Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **red**. There is little information available at a farm level with regards the quality of feed. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct CH_4) is **red**. Without the necessary data on changes in the quality of feed, it is not possible to attribute any change in GHG emission to this measure.

MM26 Feed balance

This MM covers diet formulation, inappropriate use of feeds, overfeeding protein and winter feeding and should include grazing management

Evidence for the MM would be matching diet to type of stock through diet formulation showing balance of protein and carbohydrates in particular.

The main GHG impact would be reduced methane emissions due to increased efficiency and possibly reduced nitrous oxide from manures due to a more balanced diet.

Inventory issues: unlikely to show up on agricultural inventory unless reduction in livestock numbers

a) MM flow to GHG impact

Baseline Feeding policy not based on feed characterisation and nutrient balance

↓

MM application Plan feed on quality

GHG impact	CO_2		N_2O		CH_4	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
	Stock performing to target will result in reduced emissions				**<u>Reduced emissions over lifetime and per unit of output</u>**	

b) MM characterisation and measurement

What does it mean?	Get expert help in terms of feed characterisation and rationing. Use appropriate feeds for the class and age of stock, avoid overfeeding nutrients (e.g. protein) to ensure optimal capture of nutrients. Use plant species e.g. high sugar grasses, to provide a better balance of nutrients in the rumen to promote more efficient capture of plant proteins. Pig and poultry farmers provide more precise diets than cattle and sheep farmers as requirements are more precisely known e.g. accurate amounts of essential amino acids.		
Farm input	More expensive		
Farm output	Improved feed conversion efficiency (FCE) and output		
Farm practice	A more professional approach required		
Ecosystem service impacts	Regulating	Supporting	Cultural
	Regulation of	NA	NA

	water, air and soil quality ↑		

Measurement	Primary. Measurement of the implementation of this MM would require quantification in changes in feed quality, which should be measured in terms of its nutrient content. Evidence of planning of diet per livestock type and age category would also be needed. Secondary. The increase in production as a result of improved feed quality and diet planning would require farm records on livestock diet and production efficiency. The challenge here is to keep the farm level records on feed quality and production together to demonstrate a cause and effect relationship.
Building blocks	Primary **Feed intake** / **Nutrient composition of feed (new)** / **Diet plans (new)** / **Livestock number by species** Secondary **Meat production by species** / **Egg production by species** / **Milk production by species**
Data Requirements	Primary • Feed intake (calories per head) to be collected per livestock type and age at a farm level. • Nutrient composition of feed (e.g. % protein content, % carbohydrate, % fibre) to be collected per livestock type at a farm level. • Number of farms with diet plans by livestock type. • Number of livestock of each type (e.g. dairy, beef, sheep) and age (e.g. calves, yearlings, two-year olds, adults) to be collected at a farm level. Secondary • Meat, egg and milk production (Kg, #, L per head) to be collected at a farm level.
Existing Data Sources	Primary • June Agricultural Survey – collects data on livestock numbers by type per holding. • Scottish Agriculture output, input and income statistics – presents information on inputs (e.g. feedstuffs, veterinary expenses and medicines) in £M and volume indices BUT no related data on feed quality. Quality could be inferred from average price per head by farm type and size. Secondary • Farm Accounts Survey – collects information on the average value of agricultural outputs such as meat, eggs and milk by farm type and size. These could be converted to weights or volumes based on unit market price. • Scottish Agriculture output, input and income statistics – presents information on outputs (e.g. finished livestock, livestock products), both in terms of monetary value and 000

	tonnes carcase weight, million litres of milk, millions of eggs. • Slaughterhouse data – deadweight fat class. Needs to be linked back to farm-level data on feed quality via animal ID.
Potential for new data sources	Primary A survey of livestock farms every 2-3 years asking questions on their feeding plan would be beneficial. Could also ask questions on production so that this could be directly related to changes in feed quality. Should be stratified by robust farm type and size.
Conclusions	Primary The potential for existing data sources to successfully capture uptake of the measure is **red**. There is little information available at a farm level with regards the quality of feed and diet plans. Secondary The potential for existing data sources to successfully capture the major GHG impact (direct CH_4) is **red**. Without the necessary data on changes in the quality of feed, it is not possible to attribute any change in GHG emission to this measure.

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