Effective performance of tools for climate action policy - meta-review of Common Agricultural Policy (CAP) mainstreaming

Specific contract number 340202/2014/688088/SER/CLIMA.A.2 implementing Framework Contract CLIMA.A.4/FRA/2011/0027

Report for European Commission - DG Climate Action

Ricardo-AEA/R/ED60006/Mitigation Potential
Issue Number V1.1
Date 08/01/2016

Customer:

European Commission - DG Climate Action

Customer reference:

Specific contract No 340202/2014/688088/SER/CLIMA.A.2 implementing Framework Contract CLIMA.A4/FRA/2011/0027

Confidentiality, copyright & reproduction:

Contact:

James Tweed
Ricardo-AEA Ltd
Gemini Building, Harwell, Didcot, OX11 0QR
t: 01235 75 3007
e: james.tweed@ricardo-aea.com

Ricardo-AEA is certificated to ISO9001 and ISO14001

Author:

Hugh Martineau, Jeremy Wiltshire, J Webb, Kaley Hart, Clunie Keenleyside, David Baldock, Harriet Bell, John Watterson

Approved By:

Hugh Martineau

Date:

08 January 2016

Ricardo-AEA reference:

Ref: ED60006/Mitigation Potential- Issue Number V1.1

Table of contents

Annexes

Annex 1	Candidate action screening
Annex 2	Assessment and ranking of candidate actions
Annex 3	Member State Mitigation Potential Information Tables
Annex 4	Additional information on administrative effort
Annex 5	Use of CAP policy tools to improve uptake of climate mitigation actions
Annex 6	March 2015 Workshop Report
Annex 7	September 2015 Workshop Report
Annex 8	Review of LULUCF consultation responses

Executive Summary

This report presents the results of a screening and scoping exercise to provide detailed information on the relevance and effectiveness of climate mitigation actions in the agriculture and land use sectors across the European Union (EU). It reviews the opportunities for mainstreaming climate action through the Common Agricultural Policy (CAP) and provides approaches for selection of actions. As a meta-review, the report assessed mitigation potential and appropriateness of climate action based on evidence available; where evidence gaps have been encountered, these have been highlighted and, where necessary, assumptions have been made based on expert judgement.

The project comprised 3 tasks.

Task 1: Meta-review of mitigation potential and an assessment of policy tools and instruments for climate action. This was split into two main elements:

a. Screening of Mitigation of Actions to assess mitigation potential and feasibility,
b. Analysis of the uptake of mitigation actions within the CAP and potential for future uptake.

Task 2: Identify and assess how identified (existing or new) actions could be further developed with regards to synergies and efficiency of related climate benefits:

a. Inventory assessment; determination of IPCC key categories and ability to account for mitigation actions;
b. Assessment of administrative effort for implementation of action;
c. Assessment of barriers to uptake and recommendation for how the CAP can increase uptake.

Task 3: Provide support in the assessment of the impact of the proposals for agriculture and land.

Task 1 consisted of a preparation of a long list of potential mitigation actions that may be appropriate for implementation to reduce GHG emissions in the EU. A list of actions was developed based on recent literature, including recent work undertaken for DG CLIMA, and Marginal Abatement Cost Curve reports, among other data sources. The list was discussed and agreed in consultation with DG AGRI and DG CLIMA. The initial screening reviewed the appropriateness of each of the actions against the following criteria:

- GHG emissions abatement and removal,
- Accountability and verifiability,
- Costs of implementation,
- Technological constraints,
- Benefits and Risks,
- Socio-economic factors.

The output from the screening activity was a screening report (Annex 2) and provided a basis for shortlisting actions for further assessment. The process reduced the number of actions assessed from 29 to 22, and the shortlisted actions are listed below.

List of Mitigation Actions

Group	Mitigation actions
Land Use	• Conversion of arable land to grassland to sequester carbon in the soil • New agroforestry • Wetland/peatland conservation/restoration • Woodland planting • Preventing deforestation and removal of farmland trees • Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land
Crop Production	• Reduced Tillage • Zero Tillage • Leaving crop residues on the soil surface • Ceasing to burn crop residues and vegetation • Use cover/catch crops
Livestock Production	• Livestock disease management • Use of sexed semen for breeding dairy replacements • Breeding lower methane emissions in ruminants • Feed additives for ruminant diets • Optimised feeding strategies for livestock
Nutrient and Soil management	• Soil and nutrient management plans • Use of nitrification inhibitors • Improved nitrogen efficiency • Biological N fixation in rotations and in grass mixes
Energy	• Carbon auditing tools • Improved on-farm energy efficiency

In parallel with the screening activity, there was an assessment of policy measures that may be appropriate for mainstreaming and promoting additional climate action, and to what degree existing CAP implementation at a Member State level promoted climate action. Although the role of the CAP was assessed in detail, the project was not an evaluation of the CAP.

It was concluded that the implementation of most of the climate mitigation actions identified in this study, as having the greatest mitigation potential in Member States, can be supported via the CAP. However, it has not been possible to elicit the extent to which these CAP policy mechanisms are either currently available to farmers in Member States or subsequently taken up by farmers, as the data on the utilisation of most Pillar 2 rural development measures were not available at the level of detail required for this type of assessment.

A major input to Task 1 was a successful workshop held in March 2015 which brought together researchers, NGO's and policy makers to provide input to the selection of appropriate actions and share experiences relating to effectiveness and implementation. This provided a useful base for providing both additional scientific literature and expert judgement based on experiences.

Task 2 explored the implementation of the mitigation actions further, offering insight into the challenges associated with inventory reporting before developing an approach that would provide some indicative quantification of mitigation potential at a member state level for each of the actions assessed. A further sub-task of reviewing barriers and administrative burdens on managing authorities was also undertaken.

The analysis of National Inventory Reports uncovered some interesting challenges in accounting for mitigation activities. We found that not all mitigation activities would be recognised in inventories and this depends on the methodology used by Member States and the level of sophistication in data collection and management. We found that the ability to account for mitigation actions may:

- Have a detectable impact on the emissions shown in the inventory and the impact can be specifically attributed to the implementation of the mitigation action;
- Have an impact on the emissions shown in the inventory but the effect cannot be specifically attributed to the implementation of the mitigation action;
- Have no detectable impact on the emissions shown in the inventory but may improve carbon intensity of production;
- Have no direct impact on inventories.

A key output from the project has been the quantification of mitigation potential at a Member State level. Although there was relatively robust, if at times wide ranging, evidence for the mitigation potential of actions on an area (per Ha) or livestock unit basis, scaling this activity to Member State and NUTS 2 areas proved challenging. This was primarily because limited information was available on existing uptake. Estimates have been made on the potential additional uptake based on 'expert judgement'. A methodology for assessment on regional and national scale has been suggested in chapter 4 which would provide more robust mitigation assessment. An overview of the results can be found in the table below.

Of the 22 mitigation actions for which we assessed mitigation potential, 11 showed significant potential (more than 500 kt CO_2e/y at EU level). Of these, eight were related to land use, land use change or crop production, and were focussed on carbon sequestration; two related to mitigation of N_2O emissions from fertilizer application, and one (carbon audits) is a means of identifying relevant actions at a farm business level.

One mitigation action (zero tillage) had low overall potential, but is notable for high potential in a semi-arid regions where zero tillage can avoid the need for fallow and thus increase carbon sequestration.

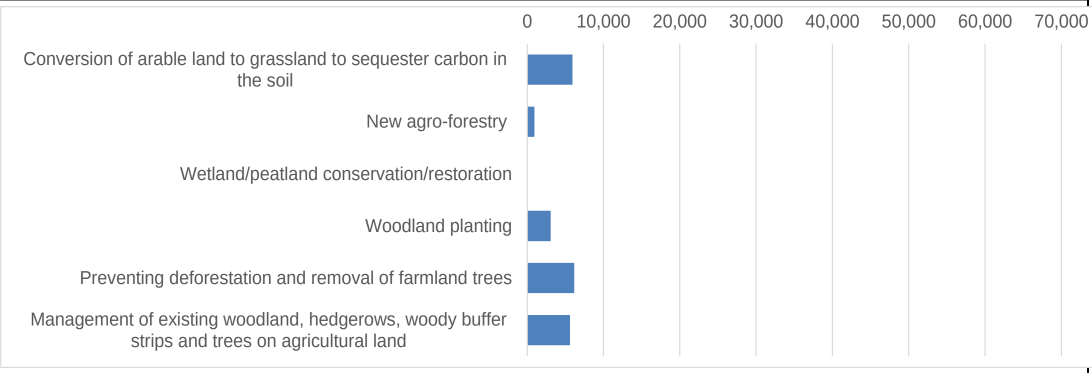
The remaining ten mitigation actions had low potential. Of these, five were livestock production measures (reflecting the technical difficulty in mitigating emissions in this farming sector); two related to efficiency of nitrogen nutrition by crops and grass (reflecting the economic incentive not to over-apply nitrogen); two related to mitigation of GHG emissions through energy savings (reflecting the relatively low contribution of energy consumption to GHG emissions in agriculture and forestry); and one is a land use action (wetland/peatland conservation/restoration) that has limited potential because it is applicable to limited areas.

An overview of the mitigation results can be found in the table below.

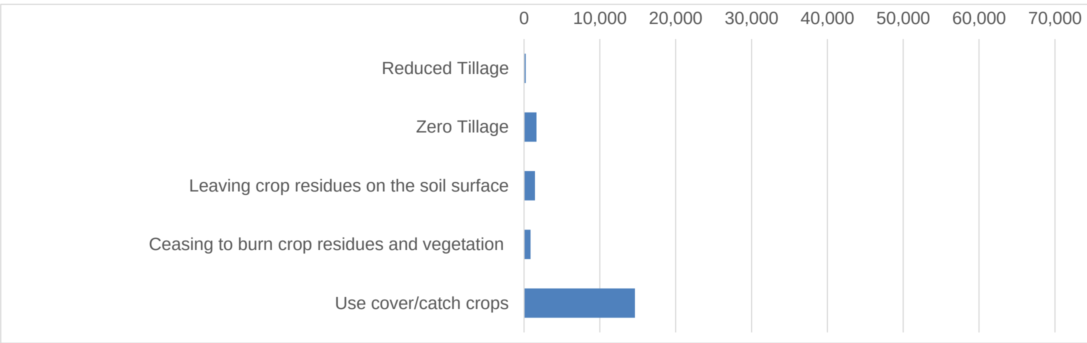
Mitigation potential summary

Group — **Mitigation actions**

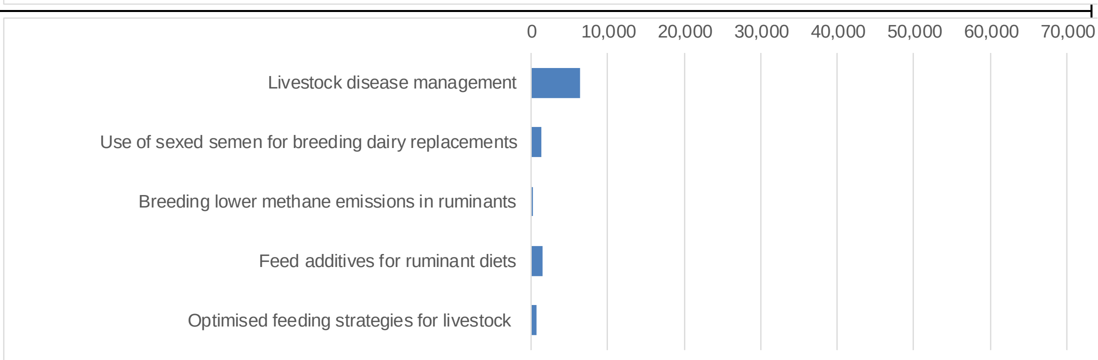
Land Use



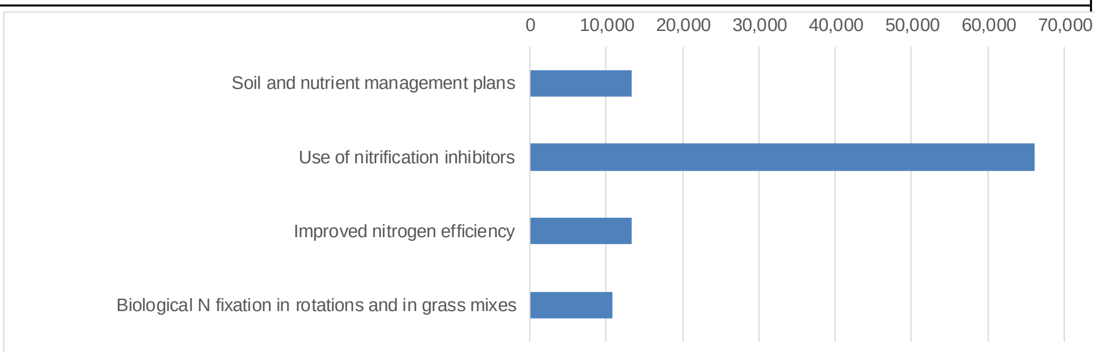
Crop Production



Livestock Production



Nutrient and Soil management



Energy

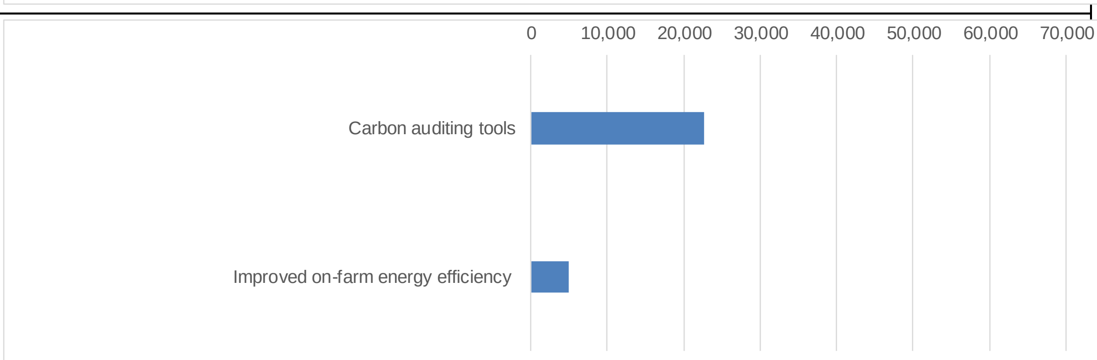


Table of Abbreviations

Abbreviation	Term
AFOLU	Agriculture, Forest and Other Land Use
BPS	Basic payment scheme
CAP	Common agricultural policy
CMEF	Common Monitoring and Evaluation Framework
CO_2e	Carbon dioxide equivalent
EAFRD	European agricultural fund for rural development
ECSFDI	England catchment sensitive farming delivery initiative
EFA	Ecological focus areas
EIP	European Innovation Partnerships
ESPG	Environmentally sensitive permanent grassland
FAS	Farm advisory system
FTE	Full time equivalent
GAEC	Good Agricultural and Environmental Condition
GHG	Greenhouse gas
IACS	Integrated administration and control system
ILUC	Indirect land use change
IPCC	Intergovernmental Panel on Climate Change
KP	Kyoto Protocol
LFA	Less Favoured Area
LPIS	Land Parcel Identification System
LU	Livestock unit
LUC	Land use change
LULUCF	Land use land use change and forestry
MA	Mitigation action
MS	Member state
NIR	National inventory report
NUTS	Nomenclature of Units for Territorial Statistics
PRTCs	Policy Related Transaction Costs
RDP	Rural development plan
SMR	Statutory management requirement
SRC	Short rotation coppice
SOC	Soil organic carbon

1 Introduction

The agriculture, land use change and forestry sectors (known as Agriculture, Forestry and Other Land Use (AFOLU) in IPCC terminology) activities in Europe have an impact on the climate, either through GHG emissions (direct and indirect), or through carbon sequestration. Some of these activities are influenced by agricultural policy mechanisms, which affect the choices made by farmers, foresters and other land managers. This report reviews relevant mitigation actions to determine the extent to which their implementation would lead to increased climate mitigation across the EU and, where possible, to quantify the mitigation potential geographically. It reviews the opportunities and challenges in implementing mitigation actions using existing policy mechanisms such as the Common Agricultural Policy and assesses the barriers at both farm and member state level.

At present, the emissions and removals from agriculture, land use and forestry are separated by different parts of the EU's climate policy. The non-CO_2 emissions from agriculture fall under the Effort Sharing Decision while CO_2 emissions and removals related to land-use and forestry are excluded from the EU's domestic reduction target but are accounted for under the Koyoto Protocol. During the course of this project a consultation process, led by DG CLIMA, was undertaken to determine how agriculture, land use, land-use change and forestry should be included in the GHG reduction target for 2030.

Agriculture accounted for about 10% of the EU's total greenhouse gas (GHG) emissions in 2012. However, when CO_2 removals by LULUCF are taken into account (304 Mt CO_2e) net emissions from the AFOLU sector were 165 Mt CO_2e. Carbon dioxide, from on-farm energy use and horticultural enterprises, accounts for only about 15% of these emissions. The majority of the global warming potential from emissions generated by agriculture are from emission of nitrous oxide (N_2O), following the application of nitrogen (N) fertilizers and livestock manures to land (c. 50%), and from emission of methane (CH_4) from enteric fermentation and manures (c. 35%).

Emissions of both N_2O and methane arise from microbial activity: in the soil (N_2O), in the digestive tracts of livestock (CH_4), and in manure (CH_4 and N_2O). This microbial activity takes place throughout the year and are often episodic, occurring mainly as a direct response to manure or fertilizer application or weather. There are actions that can be taken to reduce emissions of N_2O and CH_4 from agriculture but measuring and quantifying the effectiveness can be challenging.

There is uncertainty over the application of any mitigation action. There are well-established average abatement efficiencies for many abatement techniques that can be used for analytical purposes. However, for many GHG mitigation actions, the actual likely abatement is difficult to predict as their effectiveness depends upon current farm practice.

This report presents the results of a meta-review that brings together and reviews evidence from past reports. It assesses mitigation actions with significant mitigation/abatement potential based on existing literature and reviews the opportunities within the Common Agricultural Policy (CAP) for implementation. Phase 1 consisted of a literature review to determine the effectiveness of based on a range criteria which were:

- The ability to provide worthwhile reductions in GHG emissions or remove CO_2 from the atmosphere for long-term storage in soils or biota;
- Be compatible with practices typical of the main farming systems in the EU;
- Be verifiable by monitoring agencies;
- Not impose excessive financial burdens on the farmer;
- Be compatible with improvements in business efficiency or with other CAP environmental support measures;
- Socially acceptability;
- Sensitivity of effectiveness to farmer implementation;

- The extent to which there may be other benefits to the farmer from adoption of the MA;
- Whether there may be any adverse impacts on the environment, including leakage of GHG emissions as a result of production being diverted to regions outside the EU where there are greater GHG emissions associated with production of the crop or livestock.

There is considerable variation among Member States in the significance of agriculture as a source of GHGs; agriculture can account for up to one third of emissions in some member states. For member states with a higher proportion of emissions from agriculture, the focus on finding emissions reductions from agriculture may be greater and more challenging. Through this project, stakeholder engagement was undertaken through a workshops. The potential mitigation actions were reviewed with stakeholders which provided useful feedback on both the technical and policy feasibility of implementation.

The assessment through phase 1 provided a detailed understanding of the technical feasibility of the mitigation actions reviewed. The approach taken, assessing the effectiveness across a range of criteria, provides a holistic view of the outputs of this screening exercise are contained in the mitigation action fiches in Annex 1.

Phase 1 also reviewed the role of the CAP in promoting climate action that impacts on AFOLU sectors. The report established that there are many CAP measures which can be used to contribute to climate mitigation activities in relation to agriculture and forestry, both through conditions placed on farmers via cross-compliance, the greening payments under Pillar 1 as well as voluntary measures under rural development policy. The majority of mitigation actions identified in this study, particularly those related to the management of agricultural soils (e.g. reduced fertilizer inputs, crop rotations, reduced tillage etc.), converting arable to grassland, peatland restoration, afforestation and agroforestry can already be supported under the measures available within the CAP.

Following this process, a small number of mitigation actions were not selected for further analysis under phase 2; either due to a lack of literature or the literature not supporting the mitigation potential.

Phase 2 of the project assessed the feasibility of the implementation of the mitigation actions in policy terms. It assessed:

The ability and limitations of inventory methodologies to account for mitigation potential. National Inventory Reports were analysed to determine each member states ability to account for the impact of implementing actions.

The geographic relevance of actions aligned to mitigation potential. Farming system, land use and soils data was collated across NUTS 2 areas and used to determine the applicability of mitigation actions.

Administrative effort related to implementation. Data on administrative effort relating to implementation were sought. Quantitative information was not available from meta-data so information was sought through MS interviews which again yielded very little quantification and disparity in responses. This should be highlighted as a data gap.

Barriers to implementation. The barriers at member state level were assessed through a combination of review and interview.

The outputs are presented within this report for each of the mitigation actions reviewed and the results are summarised in the conclusions.

2 Methods

2.1 Overview

The initial screening of potential mitigation actions (MAs) to reduce GHG emissions from the AFOLU sector was carried out primarily by means of a meta-review. This meta-review was of recent, or relatively recent, reviews of the potential for GHG abatement together with the results of some recent studies to produce Marginal Abatement Cost Curves (MACCs) for the abatement of GHG emissions from agriculture.

The key studies used in the meta-analysis were those of:

- Frelih-Larsen *et al*., 2014 [Mainstreaming climate change into rural development policy post 2013].
- Buckingham *et al*., 2014 [Review of land management actions]
- Lugato *et al*., 2014 [Preserving Organic Carbon Stocks in Europe Through an Optimal Exploitation of Agricultural Crop Residues]
- Moran *et al*., 2008 [UK MACC]
- Schils *et al*., 2008 [The EU CLIMSOIL project reviewing the interrelations between soils and climate change]
- Moorby *et al*., 2007 [A UK review of a large number of MAs]

In addition to the identification of MAs, the meta-review provided information on:

- mechanisms of climate mitigation actions,
- mitigation potential to support estimates at NUTS 2 and MS scales,
- implementation feasibility including technological and socio-cultural barriers,
- environmental co-benefits and risks,
- costs to land managers,
- other factors affecting geographic relevance.

An assessment and ranking of candidate actions is provided in Annex 2, according to the following criteria:

- GHG emissions abatement and removal,
- Accountability and verifiability,
- Costs of implementation,
- Technological constraints,
- Benefits and Risks,
- Socio-economic factors.

2.2 Identification and screening of climate mitigation actions

Potential MAs were identified from existing knowledge of MAs within Ricardo Energy & Environment and IEEP, supplemented by further examination of recent scientific and technical literature from international sources and studies undertaken by the Commission. We generated a list of MAs, (Table 1) which was submitted to the Commission for approval.

Table 1: Original list of potential mitigation actions

Category	Potential mitigation action
Land management	Reduced tillage
	Zero tillage
	Retaining crop residues
	Conversion of arable to grassland to sequester carbon
	Agroforestry
	Ceasing burning vegetation and crop residues
Grassland efficiency measures	Use of grassland to reduce fire risk
Management and auditing	Carbon calculation audits
	Soil and nutrient management plans
Livestock efficiency measures	Strategies to reduce endemic disease
	Use of sexed semen for breeding dairy replacements
Manure and fertilizer efficiency	Delay applying mineral N after slurry application
	Maintain soil pH at suitable levels
	Use of nitrification inhibitors
Increased energy efficiency	Improved on-farm energy efficiency
	Increased on-farm biogas production

These MAs provided a range of options including some that have already had considerable evaluation (such as reduced tillage, retaining crop residues and the conversion of arable land to grassland), together with more innovative options such as the use of sexed semen for breeding dairy replacements, and delaying the application of mineral N to a crop to which slurry has already been applied.

The following MAs were added at the suggestion of Commission experts:

- The application of biochar to land.
- Breeding low methane emission ruminants.
- The use of additives in livestock feeds.
- Optimised livestock feeding strategies.

After discussion with the Commission at the inception meeting we added some MAs that had been evaluated in a recent project (Frelih-Larsen *et al*., 2014). These were:

- Avoid drainage of wetlands and conversion of peatland to farming;
- Improved N efficiency;
- Increasing legumes in arable rotations and in grass mixes;
- Extend the perennial phase of crop rotations;
- Use cover/catch crops and reduce bare fallow.

In addition, three woodland management MAs were included:

- Woodland creation: afforestation (including new shelterbelts, hedgerows, woody buffer strips and in-field trees) and reforestation;
- Woodland management: preventing deforestation;
- Woodland management (including existing shelterbelts, hedgerows, woody buffer strips and in-field trees).

Finally, the MA 'Soil and nutrient management plans' was divided into two MAs:

- Soil management plans;
- Nutrient management plans.

The final list of MAs for evaluation are listed in Table 2.

Table 2: Final list of potential mitigation actions

Category	Potential mitigation action
Land Use	Conversion of arable land to grassland to sequester carbon in the soil
	New agroforestry
	Wetland/peatland conservation/restoration
	Woodland planting
	Preventing deforestation and removal of farmland trees
	Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land
	Improving grassland management to increase carbon sequestration
	Use of grasslands to reduce fire risk
Crop Production	Reduced Tillage
	Zero Tillage
	Leaving crop residues on the soil surface
	Ceasing to burn crop residues and vegetation
	Use cover/catch crops
	Biochar applied to soil
	Extend the perennial phase of crop rotations
	Maintain Soil pH at suitable levels for crop/grass production
	Delay applying mineral N to a crop that has had slurry applied
Livestock Production	Livestock disease management
	Use of sexed semen for breeding dairy replacements
	Breeding lower methane emissions in ruminants
	Feed additives for ruminant diets
	Optimised feeding strategies for livestock

	Anaerobic digestion (to reduce GHG emissions during manure storage)
Nutrient and Soil Management	Soil and nutrient management plans
	Use of nitrification inhibitors
	Improved nitrogen efficiency
	Biological N fixation in rotations and in grass mixes
Energy	Carbon auditing tools
	Improved on-farm energy efficiency

Each MA was then subject to a thorough screening process. The screening process assessed their potential to reduce net GHG emissions, suitability for adoption by different farming systems in the EU, and potential compatibility with the scope of the CAP.

We also took into account, insofar as data were available, regional differences in GHG mitigation within Europe with respect to different farming and forestry systems and varying institutional and governance arrangements.

For each MA we reviewed and assessed available data and information to:

1. Produce worthwhile reductions in GHG emissions or remove CO_2 from the atmosphere for long-term storage in soils or biota;
2. Be compatible with practices typical of the main farming systems in the EU;
3. Be verifiable by monitoring agencies;
4. Not impose excessive financial burdens on the farmer;
5. Be compatible with improvements in business efficiency or with other CAP environmental support measures;
6. Be socially acceptable.

In addition other factors that could affect the usefulness of the MA were considered. These were:

7. How sensitive is the effectiveness of the MA to farmer implementation;
8. The extent to which there may be other benefits to the farmer from adoption of the MA;
9. Whether there may be any adverse impacts on the environment, including leakage of GHG emissions as a result of production being diverted to regions outside the EU where there are greater GHG emissions associated with production of the crop or livestock.

Given the existence of a number of recent reviews and appraisals of the effectiveness and applicability of mitigation options, and the relatively short duration of this project, priority was given to synthesising the findings of those reviews. However, information in other literature, principally peer-reviewed research papers, was also used to supplement gaps in the findings of the reviews or to provide more up-to-date information.

The key reviews and MACCs used were:

- Frelih-Larsen *et al.,* 2014
- Buckingham *et al.,* 2014
- Lugato *et al.,* 2014
- Pellerin *et al.,* 2013
- Schulte *et al.,* 2012
- Moran *et al.,* 2008
- Schils *et al.,* 2008
- Moorby *et al.,* 2007

The nine criteria listed above are further described and considered below in more detail.

1. Produce worthwhile reductions in GHG emissions or remove CO_2 from the atmosphere for long-term storage in soils or biota

To estimate potential net reductions in GHG emissions, we identified the following:

- The GHG(s) that will be abated by the MA.
- The proportion of the default emission that can be abated by successful application of the MA.
- The proportion of the relevant emission source to which the MA may be applied.

This information was obtained primarily by examination of recent reviews of the mitigation potential of the MAs supplemented by a systematic search of peer-reviewed literature and reports prepared for the EU and for national governments.

Some of the MAs considered for their potential to sequester C in soils may lead to an increase in N_2O emissions that to some extent will reduce the overall reduction in GHG emissions. As part of our evaluation of these MAs we assessed whether or not the potential increase in N_2O emissions was sufficiently large to nullify the C sequestration or whether any increases in N_2O were likely to be small and there would still be a net reduction in GHG emissions. For each MA where there may be an increase in N_2O emissions we make it clear whether or not this increase is likely to outweigh the increase in C sequestration.

While there have been some reports of increases N_2O emissions from the adoption of the following MAs we do not consider that the risk and size of any increases in N_2O are sufficiently great to rule out these MAs for further consideration.

- Extend the perennial phase of crop rotations
- Leaving crop residues on the soil surface
- Wetland/peatland conservation/restoration
- Use cover/catch crops

2. Be compatible with practices typical of the main farming systems in the EU

While it is likely that the MAs proposed to reduce direct emissions of N_2O and CH_4 will be potentially suitable for adoption by farmers, the uptake may be inhibited by costs of implementation, or unfamiliarity with the requirements of the action. Barriers imposed by costs and the need for specialist technical knowledge were identified by reference to peer-reviewed literature and reports prepared for the EU and for national governments, together with recommendations provided to overcome these barriers. Mitigation actions to sequester C in soils or biota are less likely to be readily adopted since they may require changes in land use, which will not be compatible with current farming systems. Hence, we considered whether this barrier may also be overcome if the costs of implementation can be met by payments under the CAP (for example to change arable land to grassland and both to woodland or agroforestry).

Given that there was little published information available on the applicability and effectiveness of the MAs in different farming systems and locations this assessment needed to be supplemented by informed expert judgement.

3. Be verifiable by Member States' monitoring agencies

All claims for CAP payments under both Pillars are subject to administrative checks, and the associated farm or forest level requirements are checked in detailed on-the-ground-checks (for example for compliance with cross-compliance standards, management requirements under agri-environment-climate contracts and technical requirements for investment projects). Typically, the on-the-ground checks are of a (risk-based) sample of beneficiaries but for some types of investment all projects will be checked. This means that any climate actions supported under the CAP must be capable of verification at the time of the compliance visit. Each MA was assessed as to whether the MA could be verified by:

- Field sampling and testing.

- Remote sensing.
- Record Inspection.
- Another approach.

4. Not impose excessive financial burdens on the farmer

If GHG-mitigation actions have not been adopted, it is likely that it is because they will impose a cost on the farming industry. However, this perception of the imposition of additional costs may be unduly influenced by the direct costs of implementation, i.e. capital costs, and an insufficient awareness of potential longer-term savings. We examined the reported costs of implementation of MAs, distinguishing between capital costs and running costs/savings. For this stage of the assessment we made use of published GHG MACC curves for the agriculture sector to indicate cost effectiveness.

5. Be compatible with improvements in business efficiency or with other CAP environmental support measures.

We assessed the degree to which MAs may be aligned to other CAP priorities. Where business efficiency and environmental benefit is associated with the implementation of an action, the case for implementation support will be greater.

6. Be socially acceptable

Actions, which may lead to net reductions of GHG emissions, may not be adopted if there is resistance to their use from consumers of the eventual food products or due to concerns over impacts on the landscape. The implications of the MA for rural employment opportunities were also taken into account. While there are reports and papers which have assessed social acceptability of mitigation options this was another part of the evaluation that required the use of expert judgement.

7. How sensitive is the effectiveness of the MA to farmer implementation?

Since many MAs require changes to farm management we estimated the extent to which the requirements of the MA could be interpreted differently by different farmers. This question has received little formal study and our knowledge and understanding of each MA was needed to determine the extent to which the success of implementing the MA would depend upon a farmer's interpretation of how the MA was to be carried out.

8. The extent to which there may be other benefits to the environment from adoption of the MA.

Many of the MAs will have other impacts on the environment. Others may have been originally developed or introduced for other environmental objectives. Such impacts are documented in reviews and peer-reviewed literature and such impacts were recorded and summarised as part of the evaluation of GHG mitigation impacts. The environmental impacts assessed were:

- Nitrate leaching.
- Pollution of watercourses by surface run-off.
- Soil erosion.
- Soil structure and stability.
- Ammonia emissions.
- Biodiversity.

9. Whether there may be any adverse impacts on the environment, including leakage of GHG emissions as a result of production being diverted to regions outside the EU where there are greater GHG emissions associated with production of the crop or livestock.

For this aspect of the impacts of adopting the MAs the same criteria were used as for 8 above, together with the risk of transferring GHG emissions to other regions (leakage) as a result of decreased production within the EU. We based our estimates of the likelihood of leakage on the reported impact of each MA on production.

Seven MAs included in the initial list and evaluated in the screening document (Annex 1) were not considered further. No estimates of the potential GHG mitigation that might arise from the implementation of those MAs were made at regional level. The section below explains why those MAs were given no further consideration. In most cases this arose from a lack of reported data on the potential effectiveness of those MAs, because the MA could only abate emissions from a very small and uncertain source, or both.

2.3 Reasons for the exclusion of the mitigation actions that we have not taken forward from the initial list

Improving grassland management to sequester carbon

The objective of this MA is to manage existing grasslands in order to increase the rate of carbon sequestration in the soil. This may require additional inputs of N fertilizer and/or livestock manures in order to increase net primary production by the grass and hence increase the amount of C that is added to soil in crops residues, root exudates or the excreta of grazing livestock.

The increase in N inputs is likely to increase N_2O emissions, and the balance between the increase in N_2O emissions and the C gain is uncertain. Buckingham *et al.,* (2014) reported that the increase in carbon sequestration by improved grassland management will vary considerably depending upon: the management practice adopted; previous management; soil type; climate. The net impact on GHG emissions will also vary greatly across the EU depending upon current grassland management practices. The effectiveness of the MA is also likely to be sensitive to farmer implementation. The degree to which an individual may implement an improved practice is likely to vary somewhat unless very prescriptive rules are devised. However, given the uncertainty over the effectiveness of individual management approaches, very prescriptive rules would not be appropriate.

As a result of these uncertainties we concluded that improving grassland management to sequester carbon was not a sufficiently robust MA to include in further analysis.

Use of grassland to reduce fire risk

Reducing fire risk is an important mitigation and adaptation action. This MA was the planting and/or managing (e.g. by grazing) of areas of grass between and among woodlands in dry areas so that the grasslands would act as firebreaks, by ensuring that dead grass and vegetative litter could not build up.

This mitigation action was not evaluated as no data were found on which to base an evaluation of this MA.

Biochar applied to soil

Biochar is a form of charcoal, produced from biomass by pyrolysis. Biochar can be added to soil, where it can increase the amount of carbon stored and amend soil properties, leading to increased oxidation of CH_4 and reduced emissions of N_2O (Smith *et al.,* 2014). The mitigation potential may arise through several mechanisms, including increased crop yields (reduced GHG emissions per tonne of product), effects on the N cycle (reduced N_2O emissions), increased carbon storage in soil, and more efficient use of mineral nutrients.

The quantity of biochar needed to reduce net GHG emissions depends on the half-life of the biochar to soil, and this is likely to be variable and, overall, is not known. Biochar may also influence the breakdown of other soil organic carbon (e.g. humus; Kleiner, 2009), which would counteract sequestration of carbon through the long-term persistence of biochar. Much of the understanding of interactions between biochar and the soil comes from laboratory studies and these interactions are not predictable, especially under field conditions (Smith *et al.,* 2014). As a result of these uncertainties, doubts remain over the effectiveness of biochar application to reduce net GHG emissions. Further research and field testing are needed to increase the understanding of the overall effects on carbon sequestration, GHG emissions and other effects on the environment.

In addition, the area of land needed for biochar feedstock production may be substantial and lead to leakage if the cultivation of feedstocks for biochar displaces agricultural production elsewhere or leads to undesirable land use change (LUC). There is much conflicting literature on this subject, with no estimates that are independent of interests in commercial development of biochar. Furthermore, the required infrastructure and feedstock supply for biochar production are not in place for immediate implementation.

Since there is considerable uncertainty over both the direct GHG consequences of biochar application to soil, as well as the uncertainties over the impacts of cultivation of feedstocks for biochar production on net GHG emissions and LUC, we concluded it was not appropriate to include this MA in the evaluation of GHG mitigation potential in the EU.

Extend the perennial phase of crop rotations

For the purpose of this project we used the definition adopted by Frelih-Larsen *et al.,* (2014) who described this MA as 'incorporating 1–3 years of a perennial crop (often alfalfa or grass hay) into annual crop rotations'.

This action is highly sensitive to the share of land used for perennial crops, and the type of perennial crops used. Carbon sequestration is also influenced by the quantity of N fertilizer used (Franzluebbers *et al.,* 2014). Gains are likely to be reversed, at least partially, because the MA would be only part of a rotation, so cultivation is likely. Reported estimates of potential C sequestration from this measure (e.g. Frelih-Larsen *et al.,* 2014) do not make clear whether the sequestration estimate takes account of cultivation on return to annual crops, and whether the area used in the calculations incudes the whole rotation or just the area of perennial crops.

Care would also be needed when adopting this MA to avoid large emissions from displaced crops, and more research is needed to predict the displacement and quantify the emissions. For these reasons, we decided that this measure should not be taken forward as a practical GHG mitigation action within the current period of CAP policy (2014 to 2020).

Delay applying mineral N to a crop that has already had slurry applied

Readily decomposable C in organic manures has the potential to enhance denitrification of NO_3^- present in soil and hence emissions of N_2O. By delaying the application of N-containing fertilizers until at least one week after slurry application, emissions of N_2O can be reduced.

Delaying the application of mineral N fertilizer until 7 to 10 days after slurry application was proposed by Stevens and Laughlin (2001) based on field experiments in which N_2O and N_2 fluxes were measured from grassland when cattle slurry (CS) and potassium nitrate (KNO_3) fertilizer were applied at the same time. However, we found no further results of work to evaluate the mitigation potential of this approach and concluded there was insufficient evidence to consider this MA further.

Maintain soil pH at suitable levels for crop/grass production

The objective of this MA is to increase the pH of acid soils since emissions of N_2O have been reported to increase as soil pH decreases below *c*. 6.0, due mainly to an increase in the ratio of N_2O to N_2. Maintaining agricultural soils between pH 6.0 and 7.0 also increases N use efficiency by crops and hence may further reduce N_2O emissions.

When lime ($CaCO_3$) is applied to reduce soil acidity, CO_2 is emitted as the $CaCO_3$ dissolves and the carbonate is released as CO_2 (Barton *et al.,* 2014). There is large uncertainty in the balance between additional GHG emissions when lime is applied, and saved emissions, especially of N_2O, as a consequence of changes to N uptake and effects on soil microbial processes. Despite the decrease in the ratio of N_2O to N_2, inconsistent relationships have been reported between N_2O emission and soil pH. As a result Lesschen *et al.,* (2011) decided not to include pH as a factor determining N_2O emissions. This uncertainty increases when the indirect effects on emissions are calculated, especially through indirect land use change.

As a result of these uncertainties we concluded that liming to increase pH was not a sufficiently robust MA to include in further analysis.

Increased on-farm biogas production

The production of biogas from livestock manures is an established technology for producing renewable energy. The potential of on-farm biogas production for reducing net GHG emissions, for both cattle and pig farms, has been reported across the EU from Spain (Marañón *et al.,* 2011) to Finland (Kaparaju and Rintala, 2011). However, for the purpose of this project, anaerobic digestion (AD) is considered only as an option to reduce GHG emissions during manure storage.

During storage of manures the GHGs CH_4 and N_2O may be emitted. Emissions of N_2O take place when crusts form on slurries which are held in open stores as a result of nitrification and denitrification of mineral N. Anaerobic digestion converts volatile carbon compounds in slurry into CH_4 during digestion, thereby reducing or eliminating the potential for CH_4 generation during storage of the digestate. The reduction in easily-degradable carbon also reduces the potential for nitrification and denitrification during subsequent storage of the digestate and hence N_2O emissions. The adoption of AD has therefore been proposed as a means to reduce emissions of CH_4 from manure storage.

Recent work by Rodhe *et al.,* (2014) indicates that, during summer, GHG emissions during manure storage may be greater from digestate than from raw slurry. No differences were reported for slurry stored over winter. Rodhe *et al.,* (2014) suggested the greater emissions of CH_4 from digestate could be the result of a larger microbe population and more active anaerobic microbes converting lignocellulose to CH_4. The lignocellulose in undigested slurry is generally resistant to breakdown during storage. The retention time in the digester was cited as 30 days by Rodhe *et al.,* (2014). This duration may have been insufficient to allow full conversion of potentially labile carbon to CH_4 during the digestion process (Wulf, 2014, pers. comm.).

No estimates were made of GHG emission reduction for this MA as the data evaluated did not indicate that GHG emissions from stored digestate would be consistently less than from storage of undigested manure. In addition, the adoption of AD only to reduce GHG emissions during manure storage will not be a cost-effective action.

2.4 Mitigation potential

The meta-review done in this project identified the potential for GHG abatement for each of the MAs. For most MAs there were multiple estimates of mitigation potential, sometimes provided as ranges. Uncertainty of GHG emissions estimates, and mitigation potential, is known to be high, but there were few estimates of uncertainty available. The mitigation potential estimates from published reviews and reports were supplemented with the results of some recent studies to produce Marginal Abatement Cost Curves (MACCs) for the abatement of GHG emissions from agriculture. We used a range for GHG abatement for each of the MAs, that reflected the values reported in the literature, taking account of relevance across the EU.

The mitigation potential values and ranges from the meta-review did not have consistent units. With respect to the units used, the MAs were in two groups:

1. Those with mitigation potential expressed as a quantity of GHG emissions per ha of land, or per head of livestock (e.g. kg N_2O per ha per year);

2. Those with mitigation potential expressed as a percentage of an emissions baseline (e.g. % of N_2O emissions from managed soils.

For the first group, we used data at NUTS 2 and MS level to estimate the mitigation potential total for each NUTS 2 area and for each MS. Data were converted to units of kt/y CO_2e per geographic area.

For the second group, for each MA in that group, we estimated baseline emissions from NIRs, for each MS. Then we applied the percentage mitigation potential values to obtain mitigation potential in units of kt/y CO_2e for each MS.

For all MAs, and for each NUTS 2 and/or MS, we then applied an uptake factor of 0.01, to provide the mitigation potential per percentage point (1%) of uptake of the MA.

The output is a series of tables, in a spreadsheet format, giving a range of mitigation potential values (minimum, maximum and median) for each MA, and for each NUTS 2 area and/or MS. These tables can be used to estimate mitigation potential for any level of uptake. Uptake was not estimated or predicted because the current level of uptake is, in most cases, unknown.

Median mitigation potential values are presented in a series of maps, showing EU NUTS 2 areas or MSs in five colour-coded groups per map, where the groups are equal divisions of the range. We also present maps to illustrate the applicability of each MA, for example, by showing the percentage of land in a relevant land use category, in each NUTS 2 area or MS (e.g. percentage of land that is arable land, to show applicability of a MA that can be applied on arable land).

Tables of median values are also presented for each MS and MA. Further data (including minima and maxima; values for NUTS 2 areas; and input data for the calculations) are provided in spreadsheet format.

2.5 Implementation feasibility including technological and socio-cultural barriers

The feasibility of the climate mitigation actions were considered from the viewpoint of the choices and decisions that would have to be made at MS level, to use the CAP to improve uptake of climate mitigation actions, in terms of the additional administrative effort required by Member States/regions and of other barriers to implementation in Pillar 1 CAP measures and RDPs.

One of the potential barriers to implementation is the additional administrative effort of implementing CAP support for climate MAs. The main area of focus is those additional activities (compared with the baseline) that may be needed to implement the chosen climate MAs under the CAP during the 2014 to 2020 period. There is little empirical data available on the scale of the costs to public administrations, for the implementation of either agricultural or climate policies. These costs vary significantly between EU MSs (and even between regions within MSs) and where studies have been carried out, the information gathered is indicative at best.

The approach taken for each of the three types of CAP measure that could be used to implement climate MAs (cross-compliance, greening payments and RDPs) was to:

- establish a baseline of existing administrative effort involved using examples of some of the administrative costs that have been identified for authorities implementing CAP measures in different MSs, from the available literature;
- use the expert judgement of the project team (several of whom have worked with managing authorities) to assess the additional administrative effort involved in preparation, implementation and monitoring/evaluation of CAP measures in two scenarios: where the climate mitigation action was already implemented by CAP

measures, but geographical coverage or uptake was to be increased; and where the climate mitigation action had to be introduced *ab initio;*

- express results as four levels of effort in terms of person months required, taking into account regional differences in costs, by providing data on average monthly staff costs for each MS.

Apart from administrative effort there are other potential barriers to MSs and regional administrations using available CAP measures to encourage uptake of climate MAs by individual farm or forest holdings. These administrative decisions will be driven by a wide range of influences, not all of them explicit in public documents, which tend to explain and justify the choices that have been made rather than options that were rejected. There is almost no literature exploring the reasons for MSs' observed CAP implementation choices, and reviewing individual RDPs was beyond the scope of this project. The barriers have been reviewed qualitatively using the available literature, semi-structured interviews with experts in selected Member States, and feedback from the project workshop on the 6th March 2015. Ways of overcoming the barriers were identified.

The effect of technological barriers and socio-cultural barriers on feasibility of implementation were considered for individual climate mitigation actions using data gathered during the screening, and also supplemented by information from semi-structured interviews with experts in selected Member States, feedback from the project workshop on the 6th March, and expert judgement of the study team. Technological barriers were assessed on the basis of:

- Whether the required technology is new or emerging,
- Availability and cost of technology,
- Lack of knowledge and training.

2.6 Costs/business benefits to land managers of implementing the MA at farm/forest level

The farm-level costs of implementing a specific climate MA will vary from farm to farm and more widely from one region to another. Although MS or regional level economic data (e.g. fixed costs and gross margin) are available for the most widely used cropping and livestock systems, this is not suitable for costing most climate MAs. The data vary in scope, format and level of detail; most mitigation actions will not be covered; and there is no EU wide synthesis of such datasets.

In the absence of comprehensive data, evidence on the farm level costs of individual climate MAs has been sourced from the available literature reviewed in the screening process, EU research projects (e.g. SmartSOIL), examples of RDP implementation from case studies and the ENRD databases. This information was supplemented by information from participants at the study workshop on 6th March 2015 and the expert judgement of the study team. The information on farm level costs was assessed in terms of investment costs, recurring costs, savings (efficiency) and income (improved productivity), to evaluate the net cost or benefit to the farm business.

2.7 Geographic relevance and mitigation potential

The mitigation actions have been assessed to determine relevance according to geographical area. Information about farming systems, land use, soil, and climatic zones have been collated from a number of data sources at NUTS 2 level (dependent on availability). Data for NUTS 2 analysis was available across all EU-28 with the exception of the UK and Germany; for these countries, geographical analysis is presented at NUTS 1 level.

The geographical relevance of a potential mitigation action is dependent on a range of factors; the parameters that we assessed relevance by are detailed in Table 3 below.

Table 3: Parameters for assessment of geographical relevance

Parameter		Measure	Data Source
Land Use	Forestry/woodland	Area	(CAPRI[1])
	Permanent grassland	Area	(CAPRI)
	Permanent crops	Area	(CAPRI)
	Arable	Area	(CAPRI)
Soil	Texture	Average % clay/slit/sand content	(LUCAS[2])
	Soil organic carbon	% area of ranges of SOC	(OCTOP[3])
	pH	Average pH	(LUCAS)
Livestock	Cattle – non-dairy	Number, density/Ha	Eurostat
	Dairy - dairy	Number, density/Ha	Eurostat
	Sheep	Number, density/Ha	Eurostat
	Goats	Number, density/Ha	Eurostat
	Pigs	Number, density/Ha	Eurostat
	Buffalo	Number, density/Ha	Eurostat
Biogeographical Zone			

The information collected was incorporated into a database and used to assess the relevance of mitigation actions across the EU. The detailed analysis of geographical relevance for each mitigation action is presented in maps in section 3 (Analysis of mitigation actions).

The relevance assessment was used to then calculate the mitigation potential on a regional basis. The mitigation potential for many of the actions is related to application of farm practices, soil or land use. By collating all this data it was then possible to scale up the mitigation potential according to the geographic circumstances.

2.8 Reporting of the mitigation effect

Background

The Kyoto Protocol legally binds developed countries to emission reduction targets. Article 5, 7 and 8 of the Kyoto Protocol provide details of the reporting and reviewing requirements for Annex 1 parties and details necessary systems and processes for the preparation of GHG inventories.

United Nations Framework Convention on Climate Change (UNFCCC) require that GHG inventory information is submitted in two parts:

[1] Common Agricultural Policy Regional Impact Analysis (CAPRI Model)
[2] Land Use/Cover Area frame Statistical Survey (LUCAS) http://eusoils.jrc.ec.europa.eu/projects/Lucas/
[3] JRC Soil Organic Carbon in Topsoils (OCTOP) Content http://esdac.jrc.ec.europa.eu/content/soil-organic-carbon-content-european-data

1. Common Reporting Format (CRF) tables: standardised data tables.
2. National Inventory Reports (NIRs): the NIRs contain descriptions of the methodologies used in the estimations, the data sources, the institutional arrangements for the preparation of the inventory (including quality assurance and control procedures), and recalculations and changes compared with the previous inventory.

The Intergovernmental Panel on Climate Change (IPCC) provides detailed guidance on how inventories should be prepared.

Our analysis reviewed both CRF tables and NIRs across the EU-28 to determine if existing and potential future approaches to inventory reporting would allow member states to accurately account for the GHG impact of implementing the mitigation actions reviewed in this study.

The IPCC provide guidance on methods and categories under which details of emissions should be reported. A complication in undertaking our analysis was that during our project the reporting framework was transitioning from one set of guidelines to another. The most recent NIRs available to us were the 2014 NIRs relating to emissions from 2012. These were reported on using 1996 revised IPCC guidelines. The 2015 reports for 2013 had been delayed due to the changes in reporting structures, and were not available at the time of our analysis.

Accounting approaches for agriculture and forestry

Volume 4 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories provides instruction for preparing annual greenhouse gas inventories of emissions in the Agriculture, Forestry and Other Land Use (AFOLU) Sector. This integrates the previously separate guidance in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories for Agriculture (Volume 3, Chapter 4) and Land-Use Change and Forestry (Volume 3, Chapter 5).

Figure 1 below illustrates the evolution from:

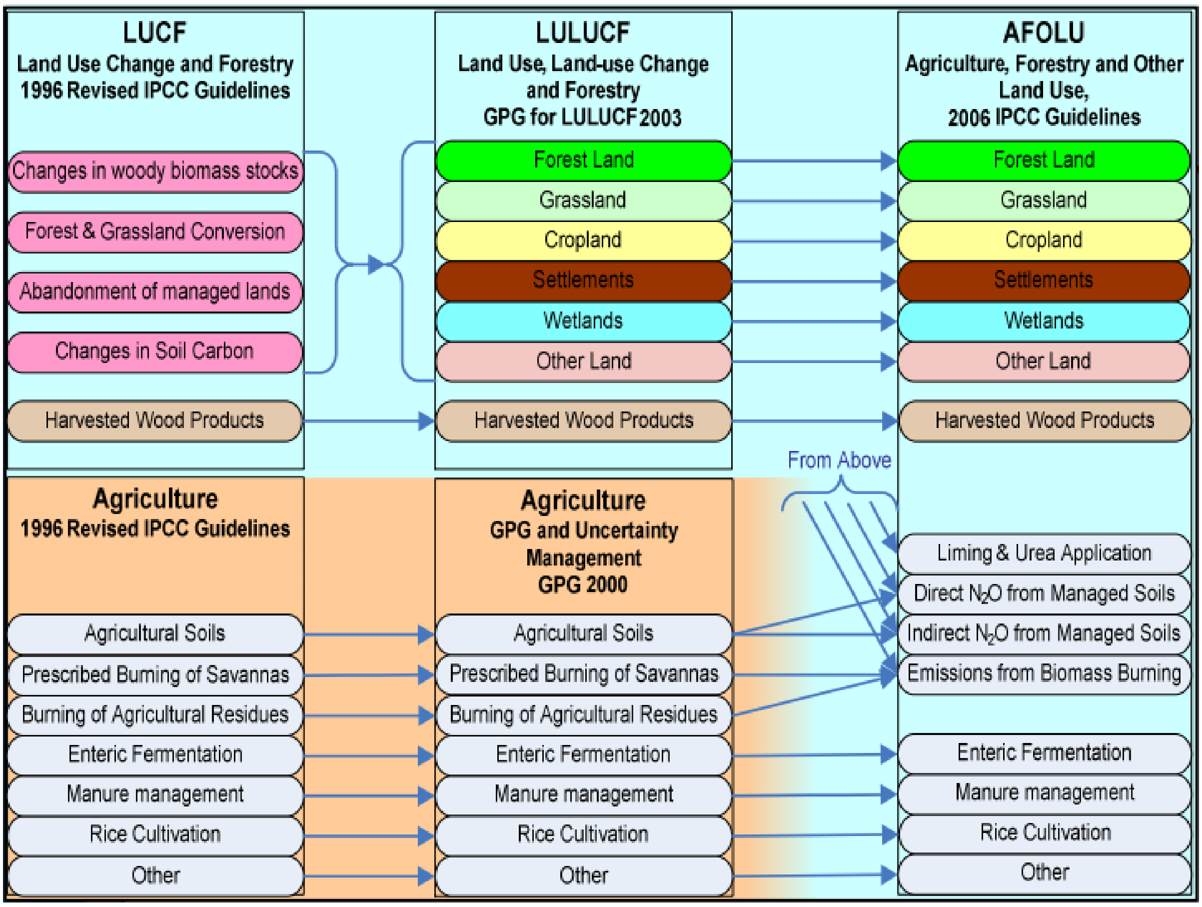
1. the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories for Agriculture;
2. the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories for Land-Use Change and Forestry;
3. the 2003 Good Practice Guidance (GPG) for Land Use, Land-Use Change and Forestry (LULUCF); and
4. the 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories;

to:

1. the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, for Agriculture, Forestry and other Land Use (AFOLU).

The six land use categories (Forest Land, Grassland, Cropland, Settlements, Wetlands, and Other Land) are sub-divided further into sub-categories: land remaining in the same category and land converted to another category. Enteric fermentation, manure management and rice cultivation remain as categories in their own right, while emissions from agricultural soils have been split into direct and indirect sources of N_2O.

Figure 1: Evolution of Agriculture Forestry and other Land-use categories



Source: IPCC

Key Categories

For NIRs submitted to the UNFCCC, it is good practice to identify Key Categories for emissions sources and sinks. The 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 1 Chapter 4, provides a methodology for identification of Key Categories. The identification of Key Categories is important as it determines the methodological approach to reduce uncertainty in the calculation of emissions. Categories that are identified as Key Categories require a more rigorous approach to calculating emissions. By identifying Key Categories, inventory compilers can focus resources on the areas where the greatest attention is required as they account for the greatest proportion of emissions.

Key Category definition: *A Key Category is one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level, the trend, or the uncertainty in emissions and removals. Whenever the term Key Category is used, it includes both source and sink categories. (IPCC)*

The Key Category analysis determines which methodological approach should be taken to calculate GHG emissions. In general for Key Categories, a higher tier (Tier 2 or 3) method should be selected. Figure 2 below details the differences between Tier 1, 2 and 3 methods.

Figure 2: Framework Structure for AFOLU methods

BOX 1.1
FRAMEWORK OF TIER STRUCTURE FOR AFOLU METHODS

Tier 1 methods are designed to be the simplest to use, for which equations and default parameter values (e.g., emission and stock change factors) are provided in this volume. Country-specific activity data are needed, but for Tier 1 there are often globally available sources of activity data estimates (e.g., deforestation rates, agricultural production statistics, global land cover maps, fertilizer use, livestock population data, etc.), although these data are usually spatially coarse.

Tier 2 can use the same methodological approach as Tier 1 but applies emission and stock change factors that are based on country- or region-specific data, for the most important land-use or livestock categories. Country-defined emission factors are more appropriate for the climatic regions, land-use systems and livestock categories in that country. Higher temporal and spatial resolution and more disaggregated activity data are typically used in Tier 2 to correspond with country-defined coefficients for specific regions and specialized land-use or livestock categories.

At **Tier 3**, higher order methods are used, including models and inventory measurement systems tailored to address national circumstances, repeated over time, and driven by high-resolution activity data and disaggregated at sub-national level. These higher order methods provide estimates of greater certainty than lower tiers. Such systems may include comprehensive field sampling repeated at regular time intervals and/or GIS-based systems of age, class/production data, soils data, and land-use and management activity data, integrating several types of monitoring. Pieces of land where a land-use change occurs can usually be tracked over time, at least statistically. In most cases these systems have a climate dependency, and thus provide source estimates with interannual variability. Detailed disaggregation of livestock population according to animal type, age, body weight etc., can be used. Models should undergo quality checks, audits, and validations and be thoroughly documented.

Source: IPCC 2006 guidelines for National GHG inventories Vol 4. Chapter 1

Our analysis shows what Key Category is or would be impacted by the implementation of the GHG mitigation actions and what methodological approach is required to accurately account for the impact.

Relevance of mitigation actions to National Greenhouse Gas Inventories, now and in the future

The review has provided links between (a) categories and Key Categories of GHG emissions used in NIRs, based on IPCC methods, and (b) the mitigation of emissions through the implementation of mitigation actions. Section 3 provides a detailed analysis of the required approaches and challenges associated with GHG accounting for each of the mitigation actions assessed.

The 2014 NIR submissions to the UNFCCC (for emissions in 2012) were the latest NIRs available to the project team, and these used the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, alongside the 2003 IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry (LULUCF). Future NIR submissions to the UNFCCC will use the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

For each mitigation action, the tables in Section 3 (Analysis of mitigation actions) summarise the methods (tiers) used by Member States (MSs) for NIRs, for the emissions that are mitigated, and show whether the mitigation action can be detected in the 2014 NIR submission. The tables also show the categories that mitigated GHG emissions will fall into under the 2006 IPCC Guidelines for National Greenhouse Gas Inventories that will be used in future NIR submissions.

This analysis proved to be complex because:

- GHG emissions in multiple categories may be mitigated by a single mitigation action,

- the IPCC methodology for determination of Key Categories results in identification of Key Categories at various levels in the emissions category hierarchy, and
- different IPCC tier methods are used for different sub-categories.

For example, for emissions from cropland, change in carbon stocks may be assessed using a different tier method, compared with non-CO_2 GHG emissions. There has been an attempt to simplify by reference to main categories where possible, and to report Key Categories and method tiers used by considering the most relevant sub-category to the mitigation action.

The analysis has focussed on the effect of each mitigation action on national inventories, and not on the GHG emissions per unit of production (efficiency effects). Efficiency effects do not necessarily result in a decrease in emissions reported in NIRs; for example, a mitigation action may increase production per ha of land area, with no change in emissions per ha of land area, giving produce with lower GHG emissions intensity, but no change in emissions at a national level assuming there are no indirect effects on production elsewhere.

2.9 References

Barton, L., Thamo, T., Engelbrecht, D., Biswas, W. K. (2014) Does growing grain legumes or applying lime cost effectively lower greenhouse gas emissions from wheat production in a semi-arid climate? Journal of Cleaner Production, 83, 194–203.

Buckingham, S., Cloy, J.M., Webb, J., Evans, C., Kuhnert, M., Moxley, J., Smith, P., Topp, C.F.E and Rees, R.M (2014) Systematic Review of the Impacts of Land Management on Carbon Sequestration in UK Relevant Soils. Green Carbon Conference, 1-3 April 2014, Brussels.

Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu, J.L., Lasorella, M.V. and Longhitano, D (2014) “Mainstreaming climate change into rural development policy post 2013.” Final report. Ecologic Institute, Berlin.

Kaparaju P and Rintala J. (2011) Mitigation of greenhouse gas emissions by adopting anaerobic digestion technology on dairy, sow and pig farms in Finland, *Renewable Energy*, 36, 31-41.

Kleiner, K (2009). The bright prospect of biochar, *Nature Reports Climate Change*, 3, 72-74.

Lesschen, J. P, Velthof, G. L., de Vries, W., Kros, J. (2011) Differentiation of nitrous oxide emission factors for agricultural soils. Environmental Pollution, 159, 3215–3222.

Lugato, E., Bampa, F., Panagos, P., Montanarella, L. and Jones, A (2014) Potential carbon sequestration of European arable soils estimated by modelling a comprehensive set of management practices, Global Change Biology, 20, 3557-3567.

Marañón E, Salter AM, Castrillón L, Heaven S, Fernández-Nava Y. (2011) Reducing the environmental impact of methane emissions from dairy farms by anaerobic digestion of cattle waste, *Waste Management*, 31, 1745–1751.

Moorby, J.M., Chadwick, D.R., Scholefield, D., Chambers, B.J., and Williams, J.R. (2007). A Review of Research to Identify Best Practice for Reducing Greenhouse Gases from Agriculture and Land Management. Final report of Defra project AC0207, October 2007, 74pp.

Moran, D., MacLeod, M., Wall. E., Eory, V., Pajot, G., Matthews, R, McVittie, A., Barnes, A., Rees, B, Moxey, A, Williams, A, Smith, P. (2008). UK Marginal Abatement Cost Curves for the Agriculture and Land Use, Land-Use Change and Forestry Sectors out to 2022, with Qualitative Analysis of Options to 2050. Final Report to the Committee on Climate Change, 20/11/2008, 152 pp.

Pellerin S., Bamière L., Angers D., Béline F., Benoît M., Butault J.P., Chenu C., Colnenne-David C., De Cara S., Delame N., Doreau M., Dupraz P., Faverdin P., Garcia-Launay F., Hassouna M., Hénault C., Jeuffroy M.H., Klumpp K., Metay A., Moran D., Recous S., Samson E., Savini I., Pardon L., 2013. Quelle contribution de l'agriculture française à la réduction des émissions de gaz à effet de serre ? Potentiel d'atténuation et coût de dix actions techniques. Synthèse du rapport d'étude, INRA (France), 92 p.

Rodhe, L.K.K., Ascue, J., Willén, A., Persson, B.V., Nordberg, A. 2014. Greenhouse gas emissions storage and field application of anaerobically digested and non-digested cattle slurry, Agriculture, Ecosystems and Environment, 199, 358–368.

Schils R, Kuikman P, Liski J, van Oijen M, Smith P, Webb J, Alm J, Somogyi Z, van den Akker J, Billett M, Emmett B, Evans C, Lindner M, Palosuo T, Bellamy P, Jandl R and Hiederer R (2008) Review of existing information on the interrelations between soil and climate change. Final Report of EU project 070307/2007/486157/SER/B1. 16 December 2008, 208pp.

Schulte, R.P.O. and Donnellan, T. (eds.), (2012) A Marginal Cost Abatement Curve for Irish Agriculture. Teagasc submission to the public consultation on Climate Policy development. Teagasc, Carlow, 30 April 2012 http://www.teagasc.ie/publications/2012/1186/1186_Marginal_Abatement_Cost_Curve_for_Irish_Agriculture.pdf

Smith P., M. Bustamante, H. Ahammad, H. Clark, H. Dong, E. A. Elsiddig, H. Haberl, R. Harper, J. House, M. Jafari, O. Masera, C. Mbow, N. H. Ravindranath, C. W. Rice, C. Robledo Abad, A. Romanovskaya, F. Sperling, and F. Tubiello, (2014), Agriculture, Forestry and Other Land Use (AFOLU). In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Stevens, R.J. and Laughlin, R.J. (2001) Cattle Slurry Affects Nitrous Oxide and Dinitrogen Emissions from Fertilizer Nitrate, Soil Science Society of America Journal, 65, 1307–1314.

3 Analysis of mitigation actions

Conversion of arable land to grassland to sequester carbon in the soil

Description

This MA is considered with respect to its potential for sequestering C in the soil when annual arable crops are replaced by grassland. This is usually done by seeding with appropriate grass mixes, or by undersowing the previous arable crop. This MA is most suited to marginal arable land that was historically kept as grazing land, such as steeply sloping land or shallow soils (Bhogal *et al.,* 2009).

Arable land converted to grassland must be maintained as grassland to maintain the climate benefit of sequestered carbon because reversion to annual cultivation will release the C sequestered under grass.

Mode of action

Compared with annual crops, perennials (especially grasses) tend to allocate a relatively large proportion of C underground and have a greater number of days per year of active plant primary productivity, resulting in more potential biomass production and soil organic carbon (SOC) storage.

Less frequent or absence of soil cultivation decreases loss of SOC by oxidation of organic matter.

Conversion of arable land to grassland can increase SOC where SOC content is low.

Mitigation potential

Influencing factors

Table 4: Summary of influencing factors for conversion of arable land to grassland to sequester carbon in the soil

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Relevant to all arable land.
Which soil types is this MA relevant to?	This action will have a positive impact on all soil types but the impact will be greater on soils with low SOC and/or high clay content, i.e. those soils that have the greatest capacity to sequester C.
Which climatic zones is this MA relevant to?	All

The sequestration potential will be greatest for soils that have been in arable rotations because of the previous depletion of SOC. The sequestration potential will also depend greatly on both previous land use, including intensity of N application, and soil clay content and subsequent grassland management. In general, soils previously in long-term annual cultivation, with a small SOC content, will be able to sequester more C, and the capacity to sequester C increases with increasing clay content.

Arable land converted to grassland will need to be maintained as grassland because reversion to annual cultivation will release the C sequestered under grass. For example, cultivation to re-seed the grassland will release some of the carbon that has been sequestered.

Subsequent grassland management, e.g. fertilizer inputs and intensity of grazing, will influence the C sequestration potential.

After conversion of arable land to grassland, and a period of years during which sequestration occurs, an equilibrium will be reached after which there will be no further increase in carbon storage. O'Mara (2012) reported the time-scale for grassland carbon equilibrium to range from 30 to 40 years. Other studies have shown that grasslands have a large potential to store additional carbon and may continue to act as a carbon sink for longer periods of time (Poeplau *et al.,* 2011). Qian and Follett, (2002) reported SOC sequestration in golf courses continued for up to about 31 years in fairways and 45 years in putting greens, with the most rapid increase during the first 25 to 30 years after turfgrass establishment. Thus, once SOC is sequestered, it remains in the soil as long as the grassland is maintained, and sequestration rates can continue for 30 and up to 50 years.

Values

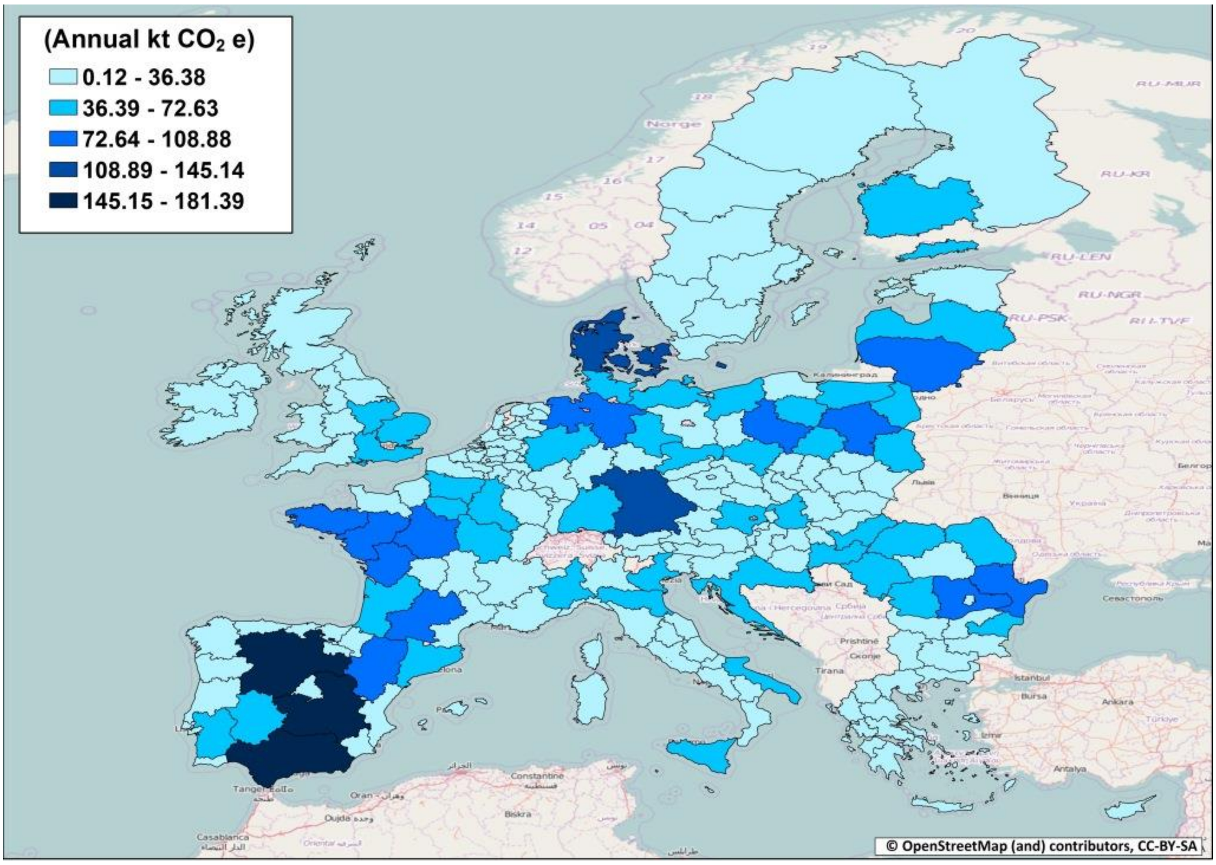
Comparisons between management systems have shown that intensively managed grasslands can sequester over 2 t C ha^{-1} $year^{-1}$ more than extensive systems (Ammann *et al.,* 2007). Lugato *et al.,* (2014) found median annual rates of sequestration of *c*. 0.6 t/ha C up to 2020.

In practice a key issue is how the new grassland is subsequently managed. If it is managed intensively for grazing or fodder for *additional* ruminant livestock, the 2 LU/ha that could be carried by productive grassland could cancel all the GHG benefits. However, this is a complex issue because level of consumption is also relevant, together with crop displacement.

Using these published values we used a range of 2.2 to 7.3 t CO_2e sequestered in soil per ha per year.

The mitigation potential at NUTS 2 level (kt CO_2e/y) is shown in Figure 3.

Figure 3: Mitigation potential at NUTS 2 level, kt CO_2e/y.



Environmental co-benefits and risks of the MA

There are other environmental benefits of this action, additional to the effect on GHG emissions. These benefits could include:

- reduced risk of soil erosion
- if the grassland is permanent, not ploughed and reseeded, and managed at low intensity, there will also be reductions in nitrate leaching and phosphorus loss to watercourses) and for biodiversity of the soil and the habitats and species of the grassland itself.

There are also risks to the environment from implementing the action and to GHG emissions as a result of the changes to production. These risks could include:

- if the new grassland is intensively managed it may be no more biodiverse than the arable land it replaces; and heavy deposits of excreta by grazing livestock can increase nitrate and phosphorus losses, in particular by run-off in areas of high rainfall;
- additional emissions of enteric CH_4 if the increased grass production leads to increased livestock numbers, or is used to replace maize-based forage in ruminant diets. In the longer-term, unless action is taken to mitigate them, these emissions would continue after C sequestration has reached equilibrium under grassland; and
- displacement of arable crop production to other land; the extent of this effect depends on several factors including marginal costs of production and GHG emissions per tonne of product in different places.

Technological and socio-cultural barriers

The techniques of grassland establishment are well understood and documented for different soil and climatic conditions and for a range of different purposes (for example pastureland, biomass production, habitat restoration or golf courses) and continue to be refined. Farmers should be able to access relevant information without much difficulty.

Costs/business benefits of implementation to farm businesses

Introducing grassland into an existing arable system effectively changes it to a mixed arable/grassland system, with significant impacts on medium to long-term business planning and profitability. The main constraints will be the opportunity costs of converting productive arable land to extensive grassland; the possible impact on property rights (for example legal restrictions or CAP penalties limiting the option of future reversion to arable); and finding an economically viable use for the grass.

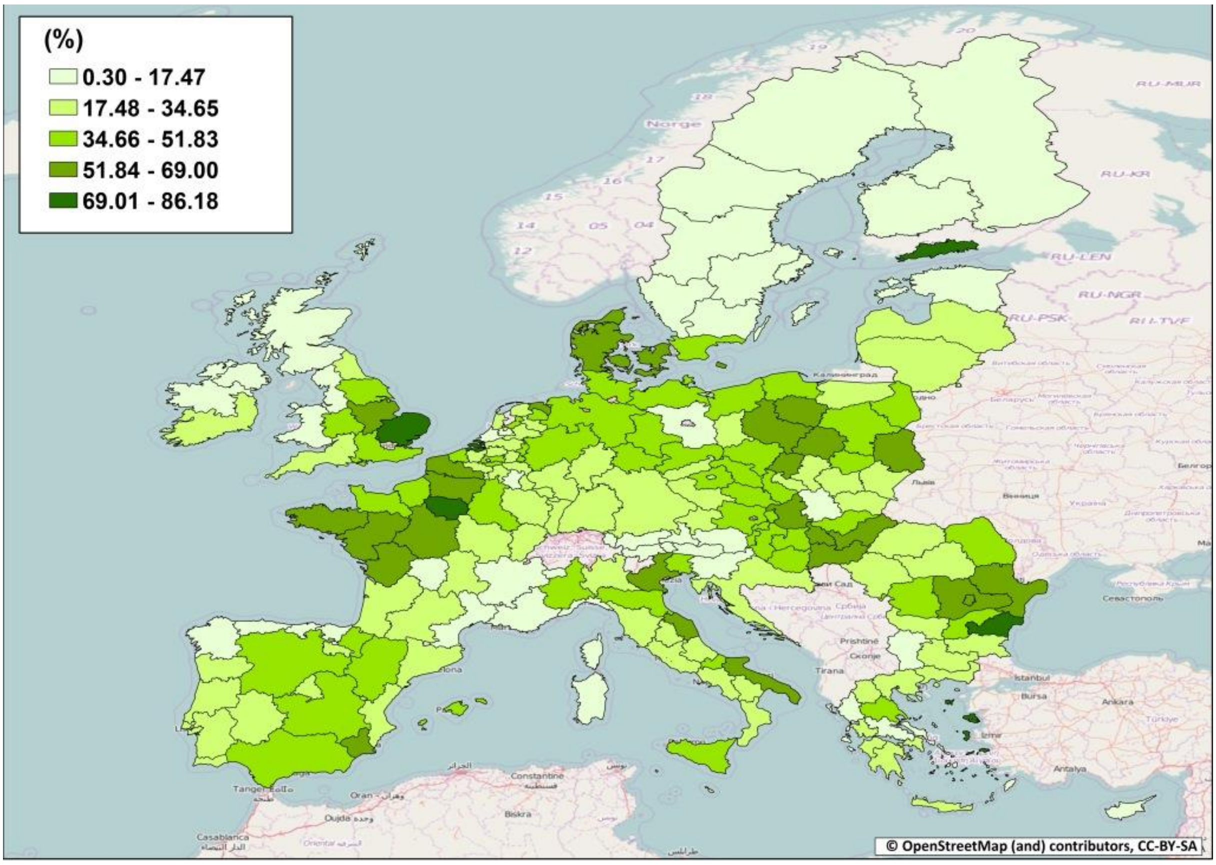
The most likely use is for livestock grazing or fodder (in the form of silage, hay or zero grazed fresh grass) for cattle, sheep and horses, but the grass may also be used as a feedstock for biogas production. If the farm does not already have livestock, or access to a biogas plant, introducing either of these ‘end uses’ will require a major change in farm practice with significant investment required in buildings, equipment and expertise. Even within an existing mixed farming system, converting arable land to permanent grassland will have some business impact, for example in terms of changing fodder crops and livestock diets. It is also counter to the long-term trend away from mixed farming towards increasing specialisation between and within livestock and arable systems.

Farmers could, if they chose to, implement this climate mitigation action in the short-term (before 2020), but it is difficult to see arable farmers being interested in introducing this action as business improvement, because it is a major change to the arable farming system and there is uncertainty about profitable end uses for grass on an arable farm.

Geographic relevance

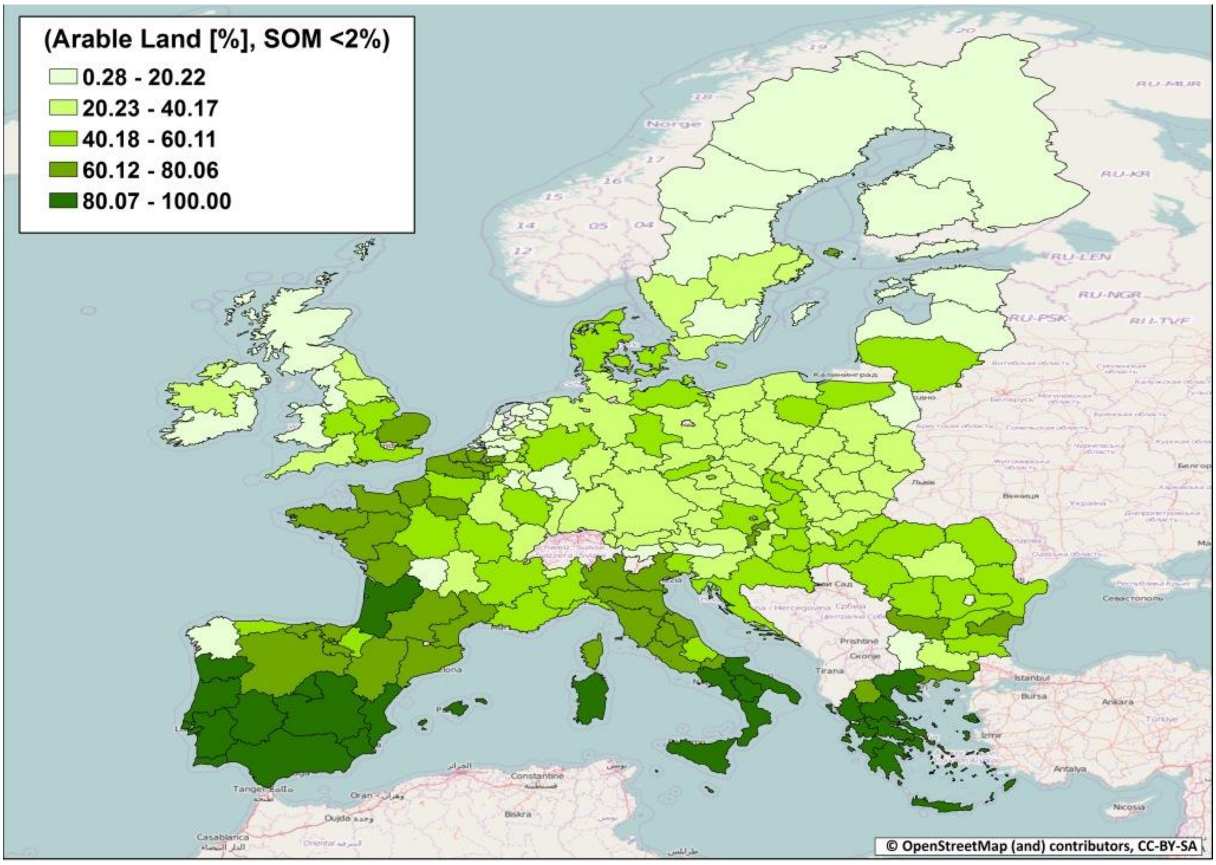
The conversion of arable land to grassland can take place only from land that is currently arable. The land currently in arable productions systems is shown in Figure 4 as the percentage of land in arable production in NUTS 2 areas.

Figure 4: Land in arable production as a percentage of total area for each NUTS 2 region



The regional circumstances that influence the relevance of this activity will vary and are likely to be influenced by regional soil and water protection priorities such as the prevention of erosion and maintenance/ improvement of SOC. Figure 5 shows the SOC map across Europe at the low end or the spectrum (less than 2% SOM).

Figure 5: Soil Organic Carbon Map (Low)



Clay content is a factor in identifying areas suitable for conversion to grassland because the capacity to sequester carbon increases with the clay content of the soil. Historically, heavier land has been more suited to grassland systems as the land is more difficult and costly to cultivate.

Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 5.

Table 5: Summary of reporting issues for conversion of arable land to grassland to sequester carbon in the soil

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes. The permanence of the impact is dependent on the period the land is in grass. Sequestration can last 30 to 50 years before equilibrium is reached. Arable land converted to grassland needs to be maintained as grassland as reversion to tillage land will release the C sequestered in previous years under grass. IPCC Guidelines have default carbon stocks for tillage land and grassland in different agro climatic zones and the implication is that reversion to cropland would lead to C loss and a return to the previous carbon stock.

Is there a methodology that will show specific impact of the mitigation action? What is it?	Yes. Refer to 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Chapter 6, 6.3.1.1. Tier 1: The effect of the Mitigation Action is detectable, divided into pools: biomass, dead OM, soil carbon. Uses default figures. Tier 2: Relies on some country-specific estimates of the biomass in initial and final land uses rather than the defaults, as in Tier 1. Includes transfer between carbon pools, which changes the emissions total Tier 3: Increases the accuracy but also has increased costs. Requires countries to have country-specific emission factors, and substantial national data.
Categories	LG: Land converted to grassland.
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Land converted to grassland
Which Member States included this as a Key Category in their 2014 National Inventory Reports	19 member states show Land converted to grassland as a Key Category AT,BE,BG,DK,EE,EL,ES,FI,FR,HR,HU,IE,LT,LU,LV,PT,SI,SK,UK
Tiers used	16 MSs use Tier 1: AT,BE,BG,EE,EL,ES,FI,HR,IE,IT,LT,LU,NL,PL,RO,SK 5 MSs use Tier 2: CZ,DK,FR,HU,SI 2 MSs use Tier 3: SE,UK Not specified: 4 Not assessed: 1
Limitations of the Inventory reporting structure	Although all tiers can report on changes, understanding the length of ley and permanence of impact requires a higher level approach. Data for land use are required. Annual data may be estimated from less frequent data sets.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

In most cases farmers will require an incentive to convert arable land to permanent grassland, because of the potential impact on the farm business.

Several sources of EU funding have been used to support the conversion of arable to grassland but it is important to note that in most cases these were neither designed nor targeted for climate mitigation but for other environmental objectives, particularly reducing the risks of soil erosion, reducing pollution from run-off into watercourses, or restoring important and threatened wildlife habitats. Also, experience of widespread implementation of the CAP measure for set-aside showed clearly that where farmers have a choice of land to be converted from arable production they are likely choose the least productive land on the farm (Areté, 2008). These factors may have some effect on the mitigation potential of the new grassland, for example in the choice of location (which may not coincide with the soil types where there is greatest mitigation potential) or in the type of after management (nature conservation objectives and some types of riparian buffer strips are most likely to be associated with low intensity permanent grassland management without ploughing and reseeding).

LIFE-Nature funding has supported the restoration of permanent grassland habitats on arable land in several projects that were focused was on habitat and species conservation but also brought benefits for soil carbon sequestration. LIFE projects usually last from 3 to 5 years and have an important role in testing and demonstrating land management and habitat restoration techniques and providing related educational and information materials. Examples from three Member States are described in Box 1.

Box 1 LIFE funding for conversion of arable land to grassland

In northern **Italy** most of the dry '*magredi*' grasslands of the Friuli lowlands have been destroyed by changes in agricultural management and some were ploughed, fertilised and irrigated for production of soybean and maize. The LIFE project aims to restore dry grassland habitats on 119 ha of cultivated land by the end of 2015, using seeds and plants of typical native species, and to produce a handbook on grassland conservation[4].

In the Hortobágy National Park in **Hungary** the Egyek-Pusztakócs area is a mosaic of dry and wet grasslands, marshes and arable land. River regulation and drainage for intensive agriculture in the 19th century resulted in the almost complete disappearance of some steppic grasslands. The ambitious aims of this four-year LIFE project included the large-scale grassland restoration in the Egyek-Puszakócs area and the reintroduction of grazing. Steppic grassland habitats were restored on a total of 747 ha of arable land, reducing the proportion of arable land within the protected area from 32% to 14%, and a grazing scheme was established involving 18 farmers/f arming companies on 2580 ha grasslands, including 820 ha grasslands not grazed before the project and the newly restored grasslands[5].

In **Denmark,** expertise on the restoration of dry grasslands has been built up since 2004 through several LIFE projects. One of the more recent projects, which aimed to restore semi-natural dry grassland habitats in the Bøjden Nor nature reserve to a favourable conservation status, was able to purchase 25 ha of neighbouring arable land and develop around 20 ha of this area as dry grassland and convert the remaining 5 ha into wetland[6].

Under CAP cross-compliance, buffer strips along watercourses have been a compulsory standard since 2007 and in many cases the requirement is for a grass strip, which may already be in place. For 2015 cross-compliance requirements, several Member States also define the GAEC 5 standard for land management to limit erosion to include arable conversion to grassland among the options (e.g. in Bulgaria between rows of permanent crops, in Estonia as buffers across hillsides).

From 2015 the CAP greening payment requirements include, for some arable farmers, the provision of EFAs most of which must be on or adjacent to arable land. Member States can decide to offer one or more types of EFA from a list of eleven, and farmers then choose which of the types on offer they will implement. Buffer strips are an EFA option in 17 Member States,

[4] LIFE MAGREDI GRASSLANDS - Restoration of Dry grasslands (Magredi) in four Sites of Community Importance of Friuli Lowland LIFE10 NAT/IT/000243
http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=4050
[5] Grassland restoration and marsh protection in Egyek-Pusztakócs LIFE04 NAT/HU/000119
http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=2667
[6] CONNECT HABITATS - Restoring dry grasslands at Bøjden Nor with a positive influence on vulnerable coastal lagoon habitat status LIFE09 NAT/DK/000371
http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=3837

and can include strips of permanent grassland but where these already exist there may be no change required in land management.

Although the measure level reports and analyses of the 2007-13 RDPs are too broad brush to permit identification of support for conversion of arable land to grassland but several Member State are known to have used the agri-environment measure (214) for this purpose, for example to combat soil erosion (Czech Republic) and for biodiversity (Finland), as described in Box 2.

Box 2 Use of agri-environment support in 2007-13 RDPs for conversion of arable land to permanent grassland.

In the **Czech Republic** arable farming in fertile areas (usually lowlands) is rather intensive both in terms of machinery and input use and there are few landscape features for wildlife. Soil erosion is a significant problem, mostly by water but also by wind in some regions, with a significant area of arable land on slopes at severe risk of water erosion. Most Czech farms are mixed, and public support to establish grassland on sites not suitable for arable farming operated as a national scheme from mid 1990s until 2004 when it became part of the entry-level agri-environment programme. By 2006 there had been an increase of 150,000 ha in the area of grassland over the whole territory. Initially the support was targeted at areas of greatest need (arable land in less favoured area (LFA) and arable fields elsewhere with soils vulnerable to erosion, for example on slopes, shallow soils and soils near water bodies). In practice this was not very efficient as fields are rather large in the Czech Republic and many have both steep slopes and flat land. The first step in improving targeting was to calculate the average slope per field, but this was not an accurate indicator of vulnerability. The next step has been to identify sensitive soils within fields, using detailed maps of soil characteristics developed by the Research Institute of Soil and Water Protection

For the 2007-13 period there was detailed field-level targeting of this soil scheme, fully integrated with the LPIS system. Farmers could download from the website a detailed map of their fields (based on LPIS) and identify which areas of the field are eligible for the arable conversion scheme. They could choose from four different types of arable conversion: to grassland; to grassland along water bodies; to grassland using a regional seed mixture; and to grassland using regional seed mixture along water bodies. This GIS-based approach is regarded as both environmentally and financially efficient, and may be extended to other entry-level schemes (for example cover crops) in the 2014-20 programming period.

In **Finland** a compulsory requirement for 'nature management fields' on arable land, aimed at resource protection and biodiversity, was introduced within the basic agri-environment scheme for the 2007-13 RDP. Farmers in agri-environment contracts had to apply it to least 5 per cent and up to 15 per cent of the arable land area, and could choose from two main options: *long-term grassland* with up to 20% legumes, not fertilised but may be used for fodder and must be mown at least once every 3 years (the bioenergy reed (*Phalaris arundinacea*) is an alternative to grass); and *three types of biodiversity field,* sown with one of three seed mixtures containing either low-competitive grasses and meadow plants, game food or amenity species to provide resources for wildlife as well as landscape benefits, which could not be used for fodder. Payments were substantial (€170/ha or €300/ha) compared to the other compulsory entry-level measures (€94/ha). The measure was very popular with farmers with participation rates in mainland Finland of 5.9 per cent in 2009, 7.4 per cent in 2010 and 6.6 per cent in 2011. The factors contributing to the success were low cereal prices with high production costs, the payment rate, flexibility in management requirements (mowing only once in three years, no biomass removal required) and the possibility of using the mown biomass or grazing the land. The clear environmental outputs of the measure (including improved soil conditions) have been quoted as incentives to join (Herzon *et al.*, 2011). Most of the parcels enrolled in this scheme were former set-aside land or fields of low fertility, awkward size or situated far from the farm. About 40 per cent of all the land entered was existing grassland or former set-aside and about 50 per cent were established after cereals (from a sample of about 100 fields) (Herzon *et al.*, 2011).

Source: Keenleyside *et al.,* (2011)

Relevant CAP measures to promote the conversion of arable land to grassland include:

- GAEC 1 buffer trips along watercourses
- GAEC 5 minimum land management to limit soil erosion
- EFA under Pillar 1 greening requirement
- support for non-productive investments linked to the achievement of agri-environment-climate objectives (M4.4) could be used to support the initial investment costs of converting arable to grassland (e.g. seed, fencing and water supplies for new pastureland)
- agri-environment-climate payments (M10.1) to compensate for the income foregone and additional costs of management compared to the previous arable production.
- where the grassland is part of an organic farming systems the measures for conversion to and maintenance of organic farming systems (M11.1 and 11.2) may be relevant.

References

Ammann C, Flechard CR, Leifeld J, Neftel A and Fuhrer J (2007) The carbon budget of newly established temperate grassland depends on management intensity, *Agriculture Ecosystems and Environment,* 121: 5–20.

Areté (2008) Evaluation of the set aside measure 2000 to 2006. European Commission. http://ec.europa.eu/agriculture/eval/reports/setaside/fulltext_en.pdf

Bhogal, A., Nicholson, F.A., Rollett, A and Chambers, B.J (2009) Best Practice for Managing Soil Organic Matter in Agriculture - Manual of Methods for 'Lowland' Agriculture, Prepared as part of Defra project SP08016.

Herzon,I., Helenius, J. Kuussaari, M., Mäkinen, T., Tiainen, J.(2010) Agri-environmental programme in Finland serving biodiversity: working forward. Aspects of Applied Biology, 100. Agri-environment schemes – what have they achieved and where do we go from here? pp 261-269

Keenleyside, C., Allen, B., Hart, K., Menadue, H., Stefanova, V., Prazan, J., Herzon. I., Clement, T., Povellato, A., Maciejczak, M. and Boatman, N. (2011) Delivering environmental benefits through entry level agri-environment schemes in the EU. Report Prepared for DG Environment, Project ENV.B.1/ETU/2010/0035. Institute for European Environmental Policy: London.

Lugato, E., Bampa, F., Panagos, P., Montanarella, L. and Jones, A (2014) Potential carbon sequestration of European arable soils estimated by modelling a comprehensive set of management practices, *Global Change Biology,* 20, 3557-3567.

O'Mara, F.P (2012) Review: part of a highlight on breeding strategies for forage and grass improvement The role of grasslands in food security and climate change, *Annals of Botany*, 110, 1263–1270.

Poeplau, C., Don, A., Vesterdal, L., Leifield J., Van Wesemael B., Schumacher J and Gensior A (2011) Temporal dynamics of soil organic carbon after land-use change in the temperate zone – carbon response functions as a model approach. *Global Change Biology,* 17: 2415–2427.

Qian, Y. L., and R. F. Follett (2002) Assessing carbon sequestration in turfgrass soil using long-term soil testing data, *Agronomy Journal*, 94, 930-935.

New agroforestry

Description

Agroforestry is the practice of integrating trees and/or shrubs with the production of food crops or livestock. This has mutual benefit for each system: the carbon stocks tend to be increased over what they would be in a farming system without trees, and the trees face less competition than in a woodland environment. Agroforestry has the ability to maintain, or even increase, tree and crop productivity under climate change whilst also providing benefits for other ecosystem services (Nair and Garrity, 2013; cited in Rivest *et al.,* 2013). Agroforestry also contributes to GHG mitigation through the production of woody biomass that can be used as a raw material and for bioenergy, replacing fossil-based materials and fuels. In this report we have evaluated Agroforestry only for its potential to sequester C in soils.

Mode of action

This mitigation action is considered with respect to its potential for sequestering C in the soil. Agroforestry is known to have an important role in carbon sequestration (Oelbermann *et al.,* 2004; Aertsens *et al.,* 2013; Baah-Acheamfour *et al.,* 2014). These systems are able to store more C than conventional arable systems (Baah-Acheamfour *et al.,* 2014).

Mitigation potential

Influencing factors

'The types of agroforestry systems and their capacities to sequester C vary globally' (Oelbermann *et al.,* 2004).

Table 6: Summary of influencing factors for new agroforestry

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Arable and grassland systems
Which soil types is this MA relevant to?	All – increased benefit on soils with low SOC
Which climatic zones is this MA relevant to?	All

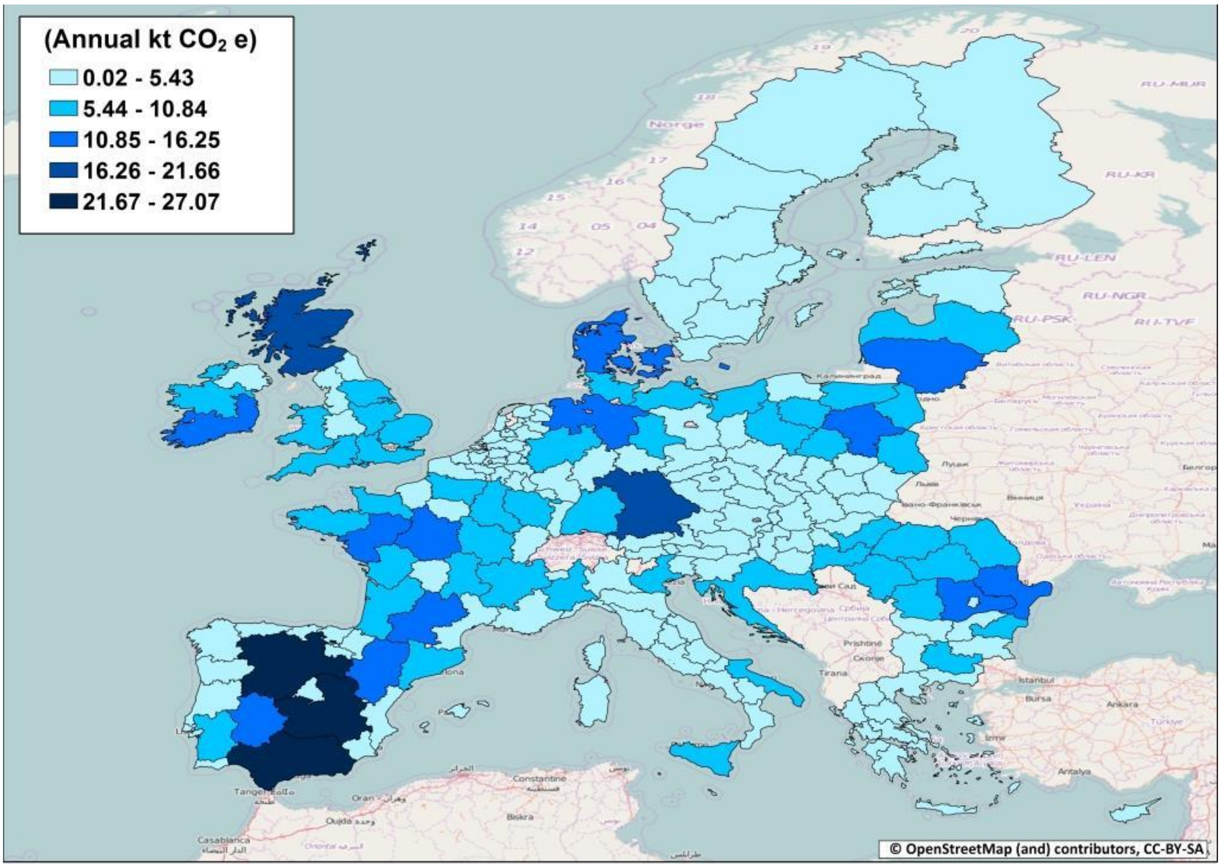
Values

Frelih-Larsen *et al.,* (2014) reported that agroforestry sequesters 138 kg carbon per hectare per year. Additionally, 'Experiments in Vézénobres (France, Mediterranean climate, sandy loam soil) indicate that poplars (140 trees/ha) of 13 years old have on average sequestered 540 kg C/tree in the trunk and 60 kg C/tree in the root system. This parcel has a potential of sequestering 6.5 tonnes C/(ha year) in the trees itself' (Aertsens *et al.,* 2013).

Agroforestry systems can vary widely (e.g. crop and tree species, crop rotation, share of land given to crops and trees, management practices used within the system), and therefore the potential for C sequestration is very variable. To reflect this variability we estimated the lower and lower values of C sequestration as ± 70% of the mean reported by Frelih Larsen *et al.,* (2014). We used a range of 0.15 to 0.88 t CO_2e sequestered in soil per ha per year.

The mitigation potential at NUTS 2 level, CO_2e/y is shown in Figure 6.

Figure 6: Mitigation potential at NUTS 2 level, kt CO_2e/y



Environmental co-benefits and risks of the MA

There are other environmental benefits of agroforestry, additional to the effect on GHG emissions. These benefits could include:

- improvements in soil moisture and efficiency of water use;
- reduced risks of soil erosion and flooding (watershed management);
- reduced NO_3^- leaching;
- improved biodiversity, depending on the tree species used and the intensity of management;
- greater structural diversity of farmland habitats and landscapes;
- improved pest control compared to monocultures;
- benefits of wind speed reduction, cooler microclimate and shade (for livestock);
- improved resilience to climate change compared to monocultures;
- more diverse soil microbial communities and improved soil fertility.

There are also risks to the environment from implementing the action, and to GHG emissions as a result of the changes to production. These risks could include:

- production displacement due to reductions in the area and yield of arable crops grown under agroforestry, leading to increased production elsewhere, possibly in regions where GHG emissions per tonne of crop or per livestock unit are greater than in the EU.
- In some circumstances, negative effects on biodiversity if non-native tree species/genotypes are grown near semi-natural woodland habitats

Both benefits and risks will vary considerably, depending on the scale at which tree crops are integrated with existing arable or grassland, the farming system, the tree species used, the intensity of subsequent management and fertilisation and the frequency of harvesting the tree crop.

Technological and socio-cultural barriers

Agroforestry has not yet been not widely used in in most countries of the EU[7], and uptake is growing slowly. The lack of practical experience and absence of reliable advice on the economics of new agroforestry systems could be a barrier to uptake, particularly as agroforestry systems are less flexible than traditional arable cropping.

Costs/business benefits to land managers of implementing the MA at farm/forest level

From the farm business point of view agroforestry is a significant change to the farming system which will require initial investment and lead to loss of some agricultural production in the short-term, but also the possibility of increased productivity from the trees, crops and livestock in the medium to long term. Agroforestry systems can vary widely in terms of crops, livestock, and tree species, crop rotations, share of land given to trees, management practices used within the system. For example, the tree crops range from high value orchard fruit, olive and carobs to fast-growing species such as poplar, and may be grown in lines, alleys or individually with annual or perennial crops or grass between the trees. Costs will include the investment and on-going costs of establishing the tree crop, and at least in the first year, income foregone from the arable crop or grass no longer grown on that land.

Farmers need to be quite motivated to adopt this practice (Aertsens *et al.,* 2013) as the introduction of agroforestry requires changes to farm management and the use of new skills, techniques or equipment. For example, field operations carried out for annual crops may need to be altered (Calfapietra *et al.,* 2010) and trees will have to be protected from damage by machinery and livestock. Farmers may not be familiar with the longer production cycle of trees compared to crops and livestock, and the effect of this on income flows and the opportunity cost of leaving the land under a tree crop rather than arable or grassland.

Farmers could choose to implement this climate mitigation action in the short-term (before 2020), but the practicalities of introducing agroforestry may be a deterrent for farmers. These include the need for initial investment, the scale at which to implement agroforestry, unfamiliarity with the management required and the consequent need for (and availability of) technical advice and support. The benefits of carbon sequestration will take several years to accrue and these depend upon continuing to grow trees on the land. Farmers may also be concerned that agroforestry planting will affect the eligibility of their land for CAP direct payments[8].

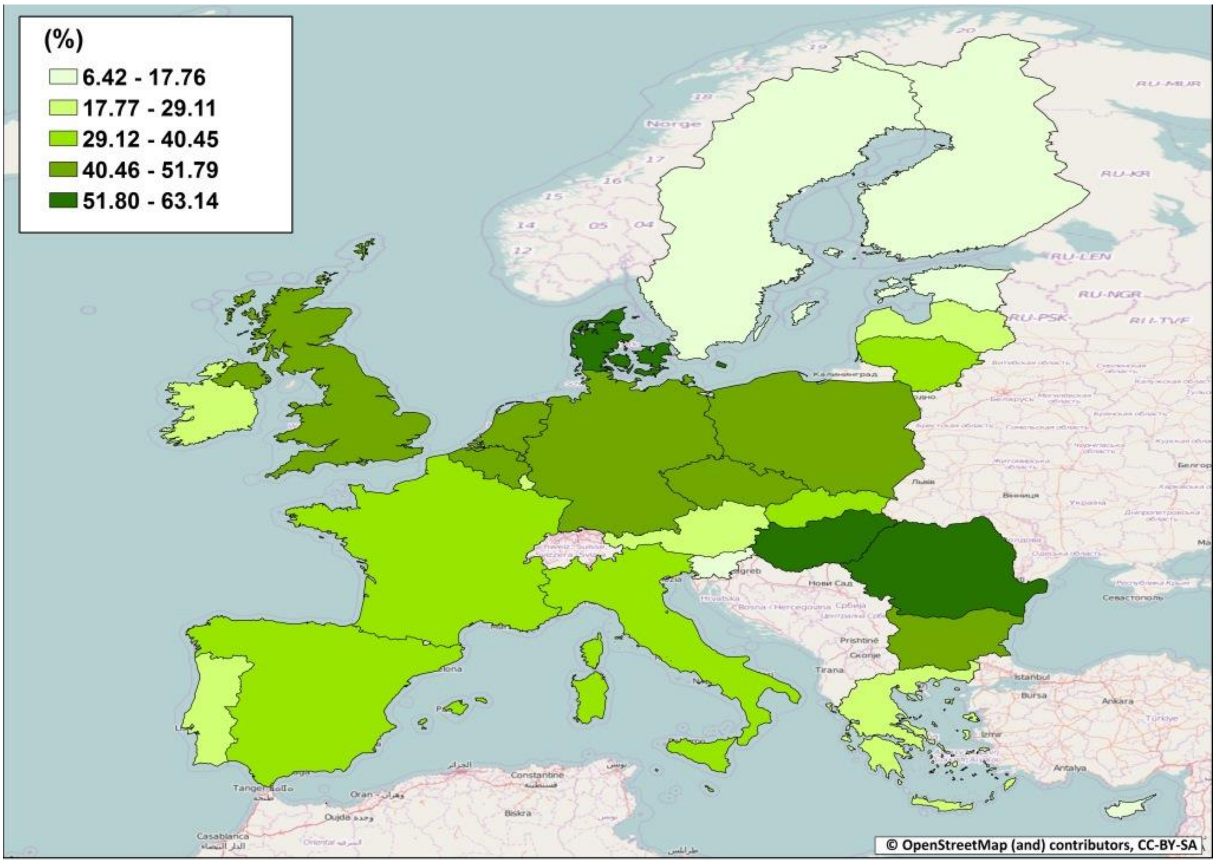
Geographic relevance

Agroforestry or short rotation forestry can be implemented on any arable or grassland, and is especially suited to land that is not extensive. The percentage of land that is currently in arable and grassland production is shown in Figure 7.

[7] This climate mitigation action refers only to agroforestry in the sense of introducing new tree crops into arable or grassland, but there are already 10.6 million hectares of long-established agroforestry in the EU, and form a significant proportion of the UAA In some countries, more than 50 per cent in Greece and Portugal, and more than 16 per cent in Spain (den Herder *et al.,* 2015).

[8] There is be an upper limit (set by the Member State) on the density of trees per hectare on land eligible for CAP direct payments.

Figure 7: Land in arable or grassland production (excluding LFAs) as a percentage of total area for each NUTS 2 region



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 7.

Table 7: Summary of reporting issues for new agroforestry

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes. Permanence of sequestration is dependent on the length of time biomass is retained. Equilibrium will be reached.

Is there a methodology that will show specific impact of the mitigation action? What is it?	Yes, Refer to 2006 IPCC Guidelines for National Greenhouse Gas Inventories Chapter 5, Cropland or Chapter 6 Grassland depending on the system agroforestry is applied to. Cropland remaining cropland (Chapter 5 5.2.1.1 (biomass)) Tier 1: shows the effect of this measure – gives default values for the accumulation of carbon in the perennial woody crops. Tier 2: Using the same assumptions but takes into account climate zones more accurately. Tier 3: More accurate – based on actual measurements or modelling. Grassland remaining grassland, (Chapter 6 6.2.1 (biomass)) Guidance offers much less methodological coverage in grassland remaining grassland chapter – no specific reference to agroforestry. Tier 1: A Tier 1 approach assumes no change in biomass in Grassland Remaining Grassland - will not account for agroforestry Tier 2: Tier 2 allows for estimation of changes in biomass due to management practices. Allows for the build-up on biomass stock Tier 3: Country specific methodology which could account for the build-up of biomass through the adoption of agroforestry with sufficient evidence.
Categories	Cropland remaining cropland Grassland remaining grassland
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Cropland remaining cropland Grassland remaining grassland
Which Member States included this as a Key Category in their 2014 National Inventory Reports	Cropland remaining cropland: 22 Member States include cropland remaining cropland as a Key Category. AT,BG,CZ,DE,DK,EE,EL,ES,FI,FR,HR,HU,IT,LT,LU,LV,PL,RO,SE, SI,SK,UK Grassland remaining grassland: 13 Member States include Grassland Remaining Grassland as a Key Category. DK,EE,FI,FR,HU,IT,LT,LU,LV,NL,RO,SE,UK

Tiers used	Cropland remaining Cropland 19 MSs use Tier 1: BE,BG,CZ,EE,FI,HR,LT,LU, MT,PL,RO,SI,SK 2 MSs use Tier 2: AT,HU 2 MSs use Tier 3: SE,UK Not specified: 2 Not Assessed: 3	Grassland remaining Grassland 13 MSs use Tier 1: BE,BG,CZ,EE,FI,HR,LT,LU, MT,PL,RO,SI,SK 4 MSs use Tier 2: AT,DK,EL,HU 4 MSs use Tier 3: IE,IT,SE,UK Not specified: 6 Not assessed: 1
Limitations of the Inventory reporting structure	The ability to account for accumulation of woody biomass in the Grassland remaining Grassland category means that agroforestry in grassland systems would not be accurately accounted for unless a MS had a specific method (tier 3) for accounting for this. Accuracy and collection of activity data is likely to be challenging.	

Policy measures that could be or have been used to encourage implementation of the MA in the EU

EU research funding is supporting the four-year project AGFORWARD (AGroFORestry that Will Advance Rural Development) during 2014-17. AGFORWARD[9] has four objectives:

- to understand the context and extent of agroforestry systems in Europe;
- to identify, develop and field-test innovations to improve the benefits and viability of agroforestry systems in Europe;
- to evaluate innovative agroforestry designs and practices for locations where agroforestry is currently not-practiced or is declining, and to quantify the opportunities for uptake at a field-, farm- and landscape-scale; and
- to promote the wider adoption of appropriate agroforestry systems in Europe through policy development and dissemination

Member States have had the opportunity to offer specific RDP support for establishing agroforestry on agricultural land since 2007, but this has hardly been used (the following commentary refers only to CAP measures relevant to establishing *new* agroforestry systems. The wider range of RDP measures used by Member States to support *long-established* agroforestry systems are not considered here.

In the 2007 to 2013 RDPs the agroforestry measure (222) was programmed initially in 19 RDPs but eight of them abandoned it, leaving only a minimal allocation of €9 million for 11 programmes. Even that may not all have been spent, as preliminary data shows expenditure of just €0.8 million euro by the end of 2014, from five Member States implementing six programmes (Szedlak, 2015).

Of the 2014-2020 RDPs (approved and draft versions) around 35 RDPs in eight Member States plan to offer support for establishment of new agroforestry: Belgium (1), France (16), Greece, Hungary, Italy (5), Portugal (3), Spain (5) and the UK (3), with total programmed

[9] http://www.agforward.eu/index.php/en/home-redirect.html

expenditure of around €90 million on more than 30,000 ha of new agroforestry (DG Agriculture and Rural Development. pers. comm.).

Relevant CAP measures to promote the establishment of agroforestry within existing arable and grassland systems include:

- under Pillar 1 greening requirements EFA can include areas of agroforestry that received RDP support under the 2007-14 or the 2014-20 RDPs
- demonstration activities and information for farmers unfamiliar with agroforestry (M 1.2)
- RDP support for agroforestry (M 8.2) which covers up to 80% of the establishment costs and provides an annual maintenance payment per hectare for up to five years.
- support for pilots and development of new products, practices, processes and technologies (M16.2)
- encouraging a landscape scale approach to agroforestry by supporting joint action for mitigating or adapting to climate change, (M 16.5)
- EIP operational groups and pilot projects (M 16.2)

References

Aertsens J, De Nocker L and Gobin A (2013) Valuing the carbon sequestration potential for European agriculture, *Land Use Policy*, 31, 584-594.

Baah-Acheamfour M, Carlyle C.N, Bork E.W and Chang S.X (2014) Trees increase soil carbon and its stability in three agroforestry systems in central Alberta, Canada, *Forest Ecology and Management*, 328, 131-139.

den Herder, M., Burgess, P.J,., Mosquera-Losada, M.R., Herzog, F., Hartel, T., Upson, M., Viholainen, I. and Rosati, A. (2015). Preliminary stratification and quantification of agroforestry in Europe. Milestone Report 1.1 for EU FP7 AGFORWARD Research Project (613520).

Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu, J.L., Lasorella, M.V. and Longhitano, D (2014) "Mainstreaming climate change into rural development policy post 2013." Final report. Ecologic Institute, Berlin.

George S.J, Harper R.J, Hobbs R.J and Tibbett M (2012) A sustainable agricultural landscape for Australia: A review of interlacing carbon sequestration, biodiversity and salinity management in agroforestry systems, *Agriculture, Ecosystems and Environment*, 163, 28-36.

Oelbermann M, Voroney R.P and Gordon A.M (2004) Carbon sequestration in tropical and temperate agroforestry systems: a review with examples from Costa Rica and southern Canada, *Agriculture, Ecosystems and Environment*, 104, 359-377.

Rivest D, Lorente M, Olivier A and Messier C (2013) Soil biochemical properties and microbial resilience in agroforestry systems: Effects on wheat growth under controlled drought and flooding conditions, *Science of the Total Environment*, 463-464, 51-60.

Szedlak T (2015) Agroforestry in the EU Common Agricultural Policy and in the new EU Forest Strategy (presentation to Agroforestry Conference, EXPO 2015, Milan, Italy, 12/09/2015). DG Agriculture and Rural Development, European Commission. https://euraf.isa.utl.pt/sites/default/files/pub/docs/szedlak_expo_2015.pdf (accessed 8 November 2015)

Wetland/peatland conservation/restoration

Description

This mitigation action includes consideration of both wetlands and peatlands, recognising that these overlap. We also consider both conservation and restoration. The applicability is limited to the presence of wetland/peatland, or former wetland that has been drained.

A wetland is an area where water causes anaerobic soil conditions. There are four main kinds of wetlands.

- Marsh – herbaceous species, often transitional zones around lakes and rivers.
- Swamp – forested wetland.
- Bog – wet peatland, characterised by acidic water at ground surface and low nutrient contents.
- Fen – wet peatland, characterised by alkaline water and relatively high in mineral content.

Healthy peatlands provide a long-term sink and store of carbon and have had a cooling effect on the climate (Frolking *et al.,* 2006; cited in Bonn *et al.,* 2014). Although they cover only 3% of the global land area, peat soils contain at least 550 Gt carbon, which accounts for 30% of the global soil carbon and about 75% of the total atmospheric carbon (Parish *et al.,* 2008). Degraded peatlands therefore contribute disproportionally to global GHG emissions, with approximately 25% of all CO_2 emissions from the land use sector (Bonn *et al.,* 2014).

Conservation is an action to prevent loss of wetland/peatland through drainage. Restoration requires re-wetting through blockage of drains or drainage channels (also known as grips). Following either conservation or restoration, appropriate land and water management is necessary to maximise climate benefits.

Actions can include:

- Restoration of wetlands through land consolidation, agri-environmental measures and investment measures on organic soils.
- Extensification of wetland use and /or land use on wet peat soils (paludiculture), through decreased production.
- No new drainages, renewal or deepening of drainages on organic soils.

Mode of action

This mitigation action is considered with respect to its potential for sequestering C in soil and reducing emissions of CH_4 and N_2O.

The relationship between wetlands/ peatlands and GHG emissions is complex. The fluxes of CO_2, CH_4 and N_2O vary depending on the condition and hydrological status of the wetland. The amount and type of GHG emissions depend on the water saturation in the soil, climatic conditions and the nutrient availability. The drainage of wetlands and peatlands exposes organic carbon to the air, decomposition of the organic material occurs and emits CO_2. Drained organic soils with low water tables continue to degrade and to emit CO_2, until either drainage is reversed or all peat is lost. Saturated soils however create anaerobic conditions and can release CH_4 and N_2O. Soil temperature can increase significantly following drainage, increasing the rate of C losses from peat soils.

Restoration of wetlands help to reduce GHG emissions from decomposition of peat and restoring the natural water table of drained wetlands. With an increased water table in organic, carbon-rich soils, accumulation of organic substances is greater than the decomposition, which facilitates the conservation and accumulation of peat and reduces the carbon release from these soils (Frelih-Larsen *et al.,* 2014).

Mitigation potential

Influencing factors

Table 8: Summary of influencing factors for wetland/peatland conservation/restoration

Relevance to farming systems, soil types and climatic zones		
	Wetland/peatland conservation	**Wetland/peatland restoration**
Which farming sectors/systems is this MA relevant to?	Extensive livestock, seasonal grazing	Crop production; extensive livestock, seasonal grazing
Which soil types is this MA relevant to?	Soils with High SOC	High SOC, Peat
Which climatic zones is this MA relevant to?	Boreal, Continental North, Atlantic North	Boreal, Continental North, Atlantic North

Values

The GHG abatement will depend on the degree of previous drainage and the current land use intensity. Frelih-Larsen *et al*., (2014) reported abatement rates for restoration and extensification of wetlands on page 71, Table 1. For example the mitigation potential range for restoration of wetlands is 3.1 to 7.8 t CO_2eq ha^{-1} $year^{-1}$

The net uptake factors for near-natural peatlands vary between -2.8 and -0.7 t CO_2eq ha^{-1} $year^{-1}$ (Artz *et al*., 2012; cited in Feliciano *et al*., 2013).

Emission reductions from a drained bog after ditch blocking, of 2.5 t CO_2eq ha^{-1} yr^{-1} may be expected within the first 10 years whereas climate benefits of 3.1 t CO_2eq ha^{-1} yr^{-1} will occur when peatlands are restored to near natural conditions (Bain *et al*., 2011; cited in Bonn *et al*., 2014).

Using these sources we estimated a range of 1.3 to 8.2 t per ha per year.

The mitigation potential at NUTS 2 level (kt CO_2e/y) is shown in Figure 8.

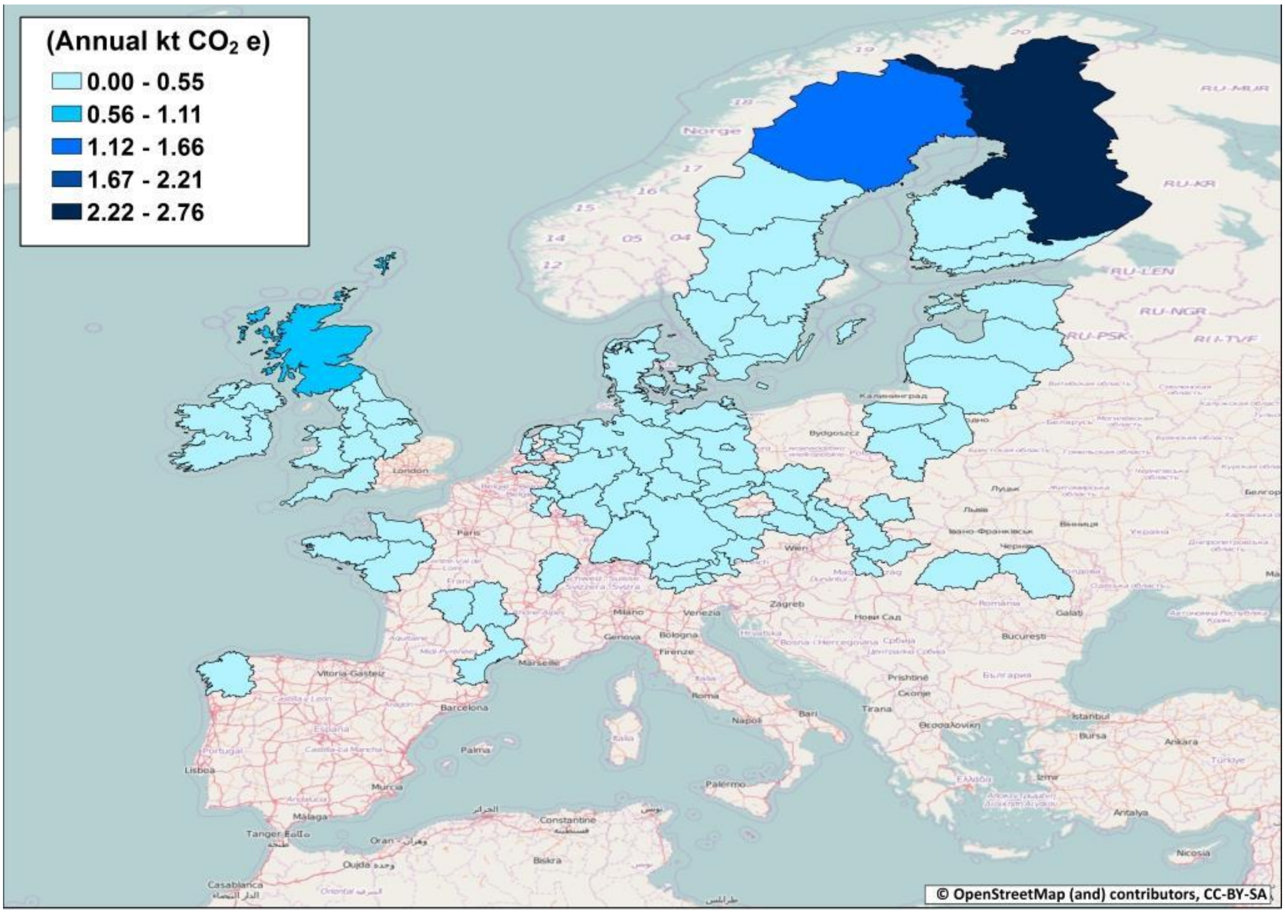


Figure 8: Mitigation potential at NUTS 2 level, kt CO_2e/y

Environmental co-benefits and risks of the MA

There are other environmental benefits of this action, additional to the effect on GHG emissions. These benefits could include:

- significant biodiversity gains from the conservation and restoration of threatened habitats (helping to meet EU Biodiversity Action Plan targets and Member State obligations for the conservation of Natura 2000 habitats and species);
- improved water quality as a result of reductions in diffuse pollution from fertilizers after conversion of arable or intensive grassland to wetland/peatland
- improved water retention and storage, with benefits for flood risk management downstream and/or on floodplains;
- reduced fire risk and reduced GHF emissions from burning dried peat as a fuel and from burning vegetation on drained upland peat soils
- reduced risk of erosion of drained organic soils.

There are also risks to the environment and to GHG emissions including:

- potential transfer of emissions from CO_2 to methane, if rewetting peat soils increases methane emissions, but in the longer term the net carbon capture is likely to outweigh this effect;
- use of rewetted peatland for some (but not all) paludiculture crops may conflict with some biodiversity objectives.

Technological and socio-cultural barriers

The techniques of peatland and wetland conservation and restoration are well understood and practical guidance is readily available, for example Joosten *et al.,* (2012). Some restoration can be relatively simple (such as blocking drainage channels) but because changes to drainage systems affect the whole of a hydrological unit, if this is a large area restoration or conservation work may involve multiple parcels of land and several different owners or managers.

Costs/business benefits to land managers of implementing the MA at farm/forest level

Maintenance of existing permanent pastures on peat soils, and conservation of existing peatlands and wetlands may incur recurrent management costs and in some cases also significant opportunity costs, depending on the type of peatland. Acid peatland has limited agricultural potential and the current productivity of most nutrient poor peatlands is generally low, mainly from extensive grazing by hardy breeds of livestock. In contrast, the opportunity cost of not draining existing fen peatland may be very high (if it has potential to be arable land or intensive grassland), but this opportunity cost will be influenced by the costs and feasibility of drainage which will vary considerably.

The restoration of peatland and wetland on existing agricultural land involves significant long-term changes in land use and farming systems, both on the restored peatland area and possibly on buffer zones needed to protect it from nutrient run-off if there is intensively managed farmland nearby. Investment may be required for new drainage infrastructure and there may be additional costs of specialist machinery, advice and management skills. The restoration costs will included the opportunity costs of ceasing conventional agricultural production, which may be very high if the starting point is productive arable land (for example vegetable production on peat soils in north-western Europe).

There may be opportunities to develop new economic uses for the restored peatland (Box 1), for example by introducing paludiculture[10]. The use of *Phragmites australis* for bioenergy or as a building material illustrates the technical and economic feasibility of paludiculture, and a database of potential paludiculture plants in one part of Germany identified 184 wetland species native to the area, with a wide range of possible uses including for energy, raw materials, medicine and animal fodder (Abel *et al.,* 2013).

Box 1 New income sources for farmers from rewetted peatlands

Carbon credits from peatland rewetting

Scientists in Germany have developed guidance for peatland projects under the global Verified Carbon Standard (VCS) and were instrumental in setting up MoorFutures[11] as the world's first voluntary carbon credits from peatland rewetting, which has been offered since 2011 by the German Federal State of Mecklenburg-Western Pomerania. A key element is the Greenhouse gas Emission Site Type (GEST) approach, developed in the University of Greifswald.

In the UK, the IUCN UK Peatland Programme[12] and partners are working in collaboration with the Government Department for Food and Rural Affairs (Defra) to explore options for drawing in carbon funds through voluntary carbon markets, corporate social responsibility

[10] Paludiculture is defineed as land management techniques that cultivate biomass from wet and rewetted peatlands under conditions that maintain the peat body, facilitate peat accumulation and sustain the ecosystem services associated with natural peatlands.

[11] http://www.greifswaldmoor.de/umsetzung-67.html

[12] http://www.iucn-uk-peatlandprogramme.org

schemes and payments for ecosystem services. The Programme has also provided an information hub which showcases peatland restoration projects in Europe and elsewhere[13].

Farmers cultivate *Sphagnum* moss as a paludiculture crop

The award winning project TORFMOOS[14] has pioneered a method of cultivating and processing *Sphagnum* moss (a characteristic plant of active wet peatlands) as a crop that can replace peat in horticultural consumer products. This provides the farmers participating in Torfmoose with an environmentally sustainable, permanent source of income from the restored raised bogs.

photo: Sabine Wichmann http://www.land-der-ideen.de/ausgezeichnete-orte/preistraeger/forschungsprojekt-kultivierung-von-torfmoos (accessed 1 November 2015)

Restoration of UK peatlands is currently being promoted as a means of both climate mitigation and adaptation. However, formal economic analysis of the relative costs and benefits of restoration is hampered by scientific uncertainty and a lack of data on biophysical conditions as well as the impacts and costs of restoration. Consequently, there is a risk that the overall level of funding and/or targeting of restoration activities may be inappropriate (Moxey and Moran 2014). Voluntary carbon markets are now trading peatland carbon, but this market has been limited by a low voluntary carbon price, combined with high verification and accreditation costs (Kossoy and Guigon, 2012; cited in Bonn *et al.,* 2014).

Farmers could choose to implement this climate mitigation action in the short to medium term (before 2020), but individual decisions will be strongly influenced by the economic impact on the farm business and possibly other factors, such as carbon markets and alternative sources of income from restored peatlands and wetlands.

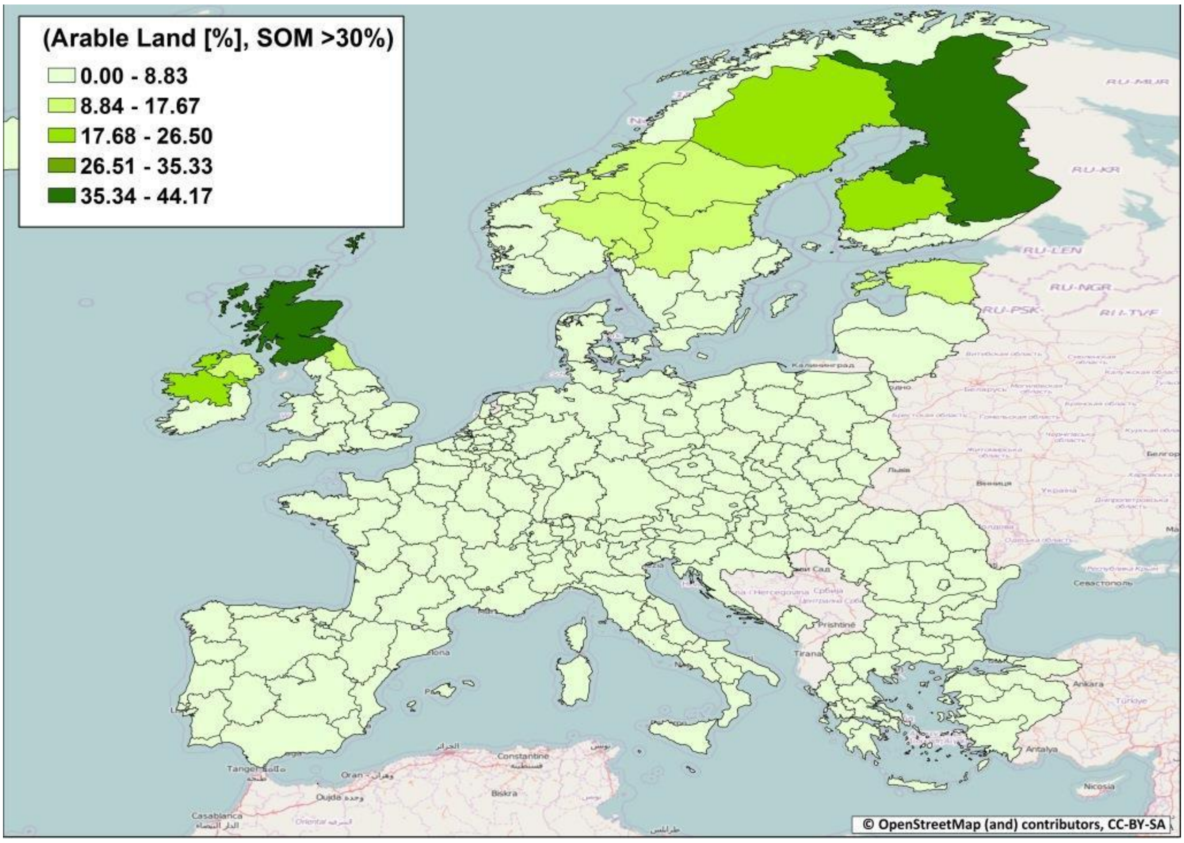
Geographic relevance

Wetland/peatland conservation/restoration is relevant where there is existing wetland/peatland, or where there is soil with high organic matter that has previously been wet and can be restored. As an indication of geographic relevance, Figure 9 shows the percentage

[13] http://www.iucn-uk-peatlandprogramme.org/peatland-gateway/gateway/europe
[14] http://www.land-der-ideen.de/ausgezeichnete-orte/preistraeger/forschungsprojekt-kultivierung-von-torfmoos (accessed 1 November 2015)

of arable land with greater than 30% soil organic matter. This land is predominantly in northern Europe.

Figure 9: Percentage of arable land with >30% SOM



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 9 and Table 10.

Table 9: Summary of reporting issues for wetland/peatland conservation

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes, Providing the correct data is collected to be able to identify the activity and the appropriate methodology is used to understand the emissions factors. Conservation is ensuring that wetland/peatland is not lost with the resultant loss of carbon. Where action is taken to retain wetlands - this will impact on the inventory were the alternative is to show a loss of wetland areas. Identifying the specific action that led to the retention of wetlands will be challenging.
Is there a methodology that will show specific impact of the mitigation action?	Identifying the impact of the action would rely on an assessment of potential wetland lost if the action were not implemented. Through our review of the National Inventory Reports across Member states, our assessment shows that the impact of wetland conservation would have an impact on the inventory by reducing losses of carbon

What is it?	however, the specific impact of the action could not be quantified in most cases. Where appropriate activity data is being collected relating to the area of wetland retained due to specific actions for conservation, it is possible to account for the impact. Guidance on measurements of the following are provided in '2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands' : CO_2 emissions and removals for drained inland organic soils 2.2.1 – methods from p2.9 onwards. Non-CO_2 emissions and removals from drained inland organic soils 2.2.2.1 – methods from p2.22 onwards N_2O emissions from drained inland organic soils 2.2.2.2 – methods from p 2.31 onwards
Categories	Wetlands remaining Wetlands
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Wetlands remaining Wetlands
Which Member States included this as a Key Category in their 2014 National Inventory Reports	5 Member States count this as a Key Category DE,DK,EE,LV,PL,
Tiers used	12 Member States use a Tier 1 approach: BE,DE,EL,ES,FI,HR,HU,IE,LU,LV,SI,UK 3 Member States use a Tier 2 approach: DK,EE,SE No Member States use a Tier 3 approach: Not specified: 6 Not assessed: 7
Limitations of the Inventory reporting structure	Quantification of the impact of the action is dependent on a comparative baseline. Activity data is likely to be a limitation to reporting the effects of this action.

Table 10: Summary of reporting issues for wetland/peatland restoration

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will	Yes. Providing accurate activity data is available.

result in a reduction in the inventory?	
Is there a methodology that will show specific impact of the mitigation action? What is it?	Yes. There as this is a simple transaction from one land category to another then the specific impact of this action should be reported on in the inventory providing the activity data is accurately collected. The accuracy of the impact will be dependent on the specific detail on how the emissions factor is calculated The guidance provided in Chapter 3 of the '2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands' provide far more detail than was previously available on CO_2 and CH_4 emissions and removals and N_2O emissions. The accuracy of the calculations on removals and emissions will increase with the tier level used 1-3.
Categories	Land Converted to Wetlands
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Land Converted to Wetlands
Which Member States included this as a Key Category in their 2014 National Inventory Reports	9 Member States record this as a Key Category. AT,DE,DK,FI,FR,NL,PL,PT,RO
Tiers used	12 Member States use a Tier 1 approach: ,BE,BG,CZ,DE,EL,FI,HR,HU,IE,LU,SI,UK 3 Member States use a Tier 2 approach: DK,EE,FR 1 Member State uses a Tier 3 approach: AT, Not specified: 4 MSs Not Assessed: 8 MSs
Limitations of the Inventory reporting structure	Accuracy depends on the methodology for accounting. Activity data is likely to be a limitation to reporting the effects of this action.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

From 2000 to 2013, 49 LIFE Nature projects focused on the restoration of degraded raised bogs, primarily in northern Europe (including 11 projects in Germany, nine in Latvia and seven in Belgium). Examples include LIFE Best Award-winners RERABOG-DK from Denmark (**LIFE05 NAT/DK/000150**) and Restoring raised bogs in Ireland (**LIFE04 NAT/IE/000121**). The ongoing German project *Hannoversche Moorgeest* (**LIFE11 NAT/DE/000344**) is aiming to optimise the hydrological balance in four large raised bogs north of Hannover to guarantee the ecological status (and carbon sink capacity) of 500 ha of active raised bogs and transition mires and some 1 000 ha of typical bog woodlands. A total of 16 LIFE Nature projects have carried out actions to restore blanket bogs, mainly in the UK and Ireland. For instance, a project in Scotland (**LIFE00NAT/UK/007075**) removed commercial forestry from 1 556 ha of land that had previously been blanket bog and through hydrological works benefited the condition of more than 16 600 ha of peatland. There have been 365 LIFE Nature projects that have directly or indirectly targeted fen restoration. Notable examples include LIFE FRIULI FENS (**LIFE06 NAT/IT/000060**), a LIFE Best Nature project 2012. In Germany, two projects (**LIFE98 NAT/D/005085** and **LIFE02 NAT/D/008456**) restored 2 200 ha of the Western Dümmer, a stopover area for migratory birds, by re-wetting drained degraded fen peatlands. The Hungarian project Grass-Tapolca (**LIFE06 NAT/H/000102**) led in surface water in two re-wetting channels to improve the hydrology of more than 100 ha of Molinia fen meadows (European Commission 2014).

The CAP greening measure requires all Member States to designate permanent grasslands in Natura 2000 as ‘environmentally sensitive grasslands’ which may not be converted or ploughed, and also offers Member States the option of giving similar protection to permanent grassland elsewhere, but only four countries have chosen to do so (for details please see Annex 5). There is no information on what proportion of the designated environmentally sensitive grassland is on peat, wetland or other carbon rich soils.

The measure level reports and analyses of the 2007-13 RDPs are too broad brush to permit identification of this climate mitigation action and no summary information is available on the 2015-2020 RDPs, but in the 2007-13 several Member States used RDP measures to restore and/or manage peatlands. For example, in 2007-13 the Netherlands used RDP funding for a meadow bird management scheme which involved raising groundwater levels in peat pasture areas and preventing further loss of permanent grassland. In Finland the creation and management of multi-functional wetlands used agri-environment support and the Leader approach. Further increase of new wetlands is expected, in line with priorities of the new 2007-13 RDP (e.g. biodiversity, management of natural resources and climate change)[15].

In Denmark detailed soil maps were used in 2007-13 to target successful peatland conservation pilot projects on farmland (including conversion of arable land that had been used for growing potatoes and carrots). The experience of these projects, in which expert advice from government environmental experts and the voluntary participation of farmers were key factors, has been used to launch new initiatives in the 2014-20 period. These are targeted at locations offering multiple benefits for biodiversity, carbon sequestration, reduced N_2O emissions, and reduced nitrate and phosphate pollution of water.

In a recent policy statement the German Environment Minister called for setting up targets and pilot projects for extensive management of lowland moor (carbon-rich soils) including rewetting these areas[16].

Where it is appropriate to promote this action, and the requirements for verification and control can be met, the relevant CAP measures could include:

- enabling farmers cultivating pauldiculture crops to claim CAP direct payments on their land, by defining these as ‘permanent crops’ or ‘agricultural products’ within the meaning of the CAP direct payments Regulation[17]

[15] EC (unpublished) Synthesis report of Member State reports on information on LULUCF actions (draft Nov 2015)

[16] http://www.bmub.bund.de/fileadmin/Daten_BMU/Pools/Broschueren/naturschutzoffensive_2020_broschuere_bf.pdf

[17] EU Regulation 1307/2013, Article 4(c) and 4(g).

- Under CAP greening requirements, prohibition of converting or ploughing designated environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere
-
- GAEC 7 Retention of landscape features (including ponds where appropriate)
- support for non-productive investments linked to the achievement of agri-environment-climate objectives (M4.4) for restoration work
- agri-environment-climate payments (M10.1) for ongoing management, including the option for applying 30% transaction costs to group contracts to facilitate management of large hydrological units
- support for prevention of damage to forests from forest fires and natural disasters and catastrophic events (M8.3)
- support for investments improving the resilience and environmental value of forest ecosystems (M8.5)
- compensation payment for Natura 2000 farmland areas (M12.1)
- compensation payment for Natura 2000 forest areas (M12.2)
- compensation payment for agricultural areas (M12.3) within river basin management plans
- payment for forest-environmental and climate commitments (M15.1)
- support for the conservation and promotion of forest genetic resources (M15.2)
- support for joint action undertaken with a view to mitigating or adapting to climate change and for joint approaches to environmental projects and ongoing environmental practices (M16.5)
- support for drawing up of forest management plans or equivalent instruments (M16.8)

References

Abel, S., Couwenberg, J., Dahms, T. & Joosten, H. (2013)The Database of Potential Paludiculture Plants (DPPP) and results for Western Pomerania. – Plant Div. Evol. 130: 219–228, DOI: 10.1127/1869-6155/2013/0130-0070. 2013.

Bonn, A. Reed, M.S., Evans, C.D., Joosten, H., Bain, C., Farmer, J., Emmer, I., Couwenberg, J., Moxey, A., Artz, R., Tanneberger, F., von Unger, M., Smyth, M., and Birnie, D., (2014). Investing in nature: Developing ecosystem service markets for peatland restoration, *Ecosystem Services*, 9, 54-65

European Commission (2014) LIFE and Soil protection. LIFE Environment. http://ec.europa.eu/environment/life/publications/lifepublications/lifefocus/documents/soil_protection.pdf

Feliciano, D., Slee, B., Hunter, C., and Smith, P., (2013) Estimating the contribution of rural land uses to greenhouse gas emissions: A case study of North East Scotland, *Environmental Science and Policy*, 25, 36-49

Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu, J.L., Lasorella, M.V., and Longhitano, D. (2014). “Mainstreaming climate change into rural development policy post 2013.” Final report. Ecologic Institute, Berlin.

Joosten H, Tapio-Biström M-L, and Tol s (eds.) (2012) Peatlands - guidance for climate change mitigation through conservation, rehabilitation and sustainable use, second edition. Food and Agriculture Organization of the United Nations and Wetlands International.

Moxey A. and Moran D (2014) UK peatland restoration: Some economic arithmetic. Science of the Total Environment, 484, 114-120, 2014. doi: 10.1016/j.scitotenv.2014.03.033

Parish, F., Sirin, A., Charman, D., Joosten, H., Minayeva, T., Silvius, M. and Stringer, L. (Eds.) 2008 Assessment on Peatlands, Biodiversity and Climate Change: Main Report. Global Environment Centre, Kuala Lumpur and Wetlands International, Wageningen.

Woodland planting

Description

We describe this action more widely than afforestation and reforestation, by including development of new farmland features that include planting of trees (shelterbelts, hedgerows, woody buffer strips and in-field trees).

According to IPCC definitions, afforestation describes forest planting activities on sites that have not been forested within the last 50 years, while reforestation refers to sites that have been stocked by forest plants within the last 50 years (SFC, 2010).

It is important to note that, in the context of carbon savings, it is assumed that measures taken in relation to forestry in Europe are permanent changes. This means that land that is afforested will remain forest. Permanence cannot be guaranteed, and the implications of this are much debated, specifically in the context of rewards that may be available for such measures and that may be linked to the global carbon market. As European countries are signatories to the Kyoto protocol, and thus signed the Marrakesh accords, they have officially committed to reporting changes in their emissions profiles that are permanent. This is, officially, a good reason to assume permanence in forestry changes. However, with a further increase in wood prices and as many European countries set up programmes to mobilise more wood from forests, there may be concerns about permanence in the future (Eisbrenner and Gilbert, 2009).

Mode of action

A major increase in the forest carbon reservoir is possible through afforestation of non-forest land.

In principle, reforestation is a precondition following harvesting activities replacing formally existing carbon stock. Hence, it is not regarded as providing sequestration potential because it is an integral part of sustainable forest management (SFC, 2010).

Mitigation potential

Influencing factors

Table 11: Summary of influencing factors for woodland planting

Relevance to farming systems, soil types and climatic zones			
	Afforestation	**Reforestation**	**Shelterbelts, hedgerows, woody buffer strips, and in-field trees**
Which farming sectors/systems is this MA relevant to?	All	All	All
Which soil types is this MA relevant to?	All	All	All
Which climatic zones is this MA relevant to?	All	All	All

Values

The IPCC estimates that the potential of afforestation in Europe is 115 Mt CO_2e / year under a cost of 100 US $ / t CO_2e (IPCC, 2007). The figure is based on an averaged output from three global forest sector models that provide estimates for all regions of the world (Sohngen and Sedjo, 2006; Sayathe *et al*., 2007; Benitez-Ponce *et al*., 2007).

Frelih-Larsen *et al.,* (2014) identified from the literature (Bhogal *et al.,* 2009; Posthumus *et al.,* 2013) that with regard to the carbon loss avoided due to reduced erosion and the increase in carbon stored:

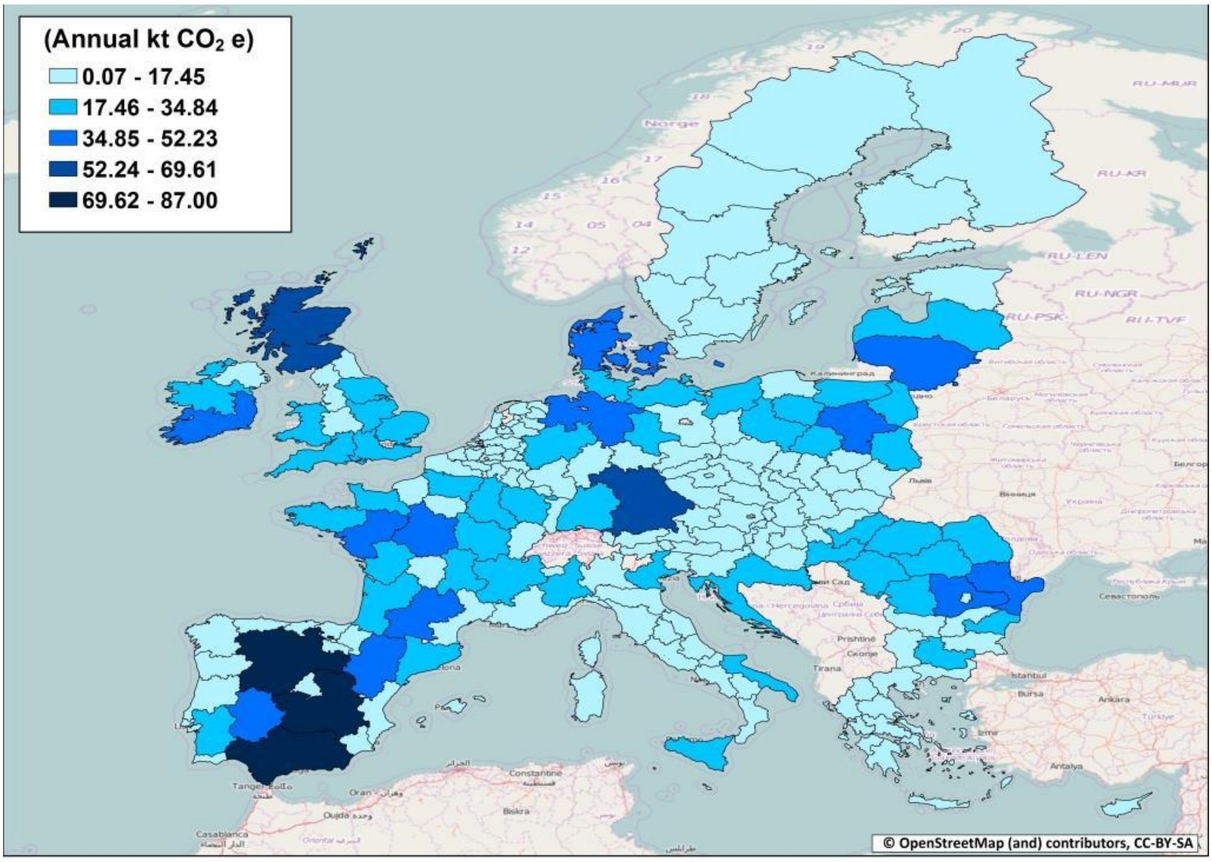
- Hedgerows have a small effect in grasslands and a moderate effect in arable fields;
- Shelterbelts have an impact of +14 kg C/ha/yr.

Of the options evaluated under this MA we have made estimates of the annual carbon sequestration potential for woodland creation from arable land as this is the best documented of the options. The values below were taken from a recent UK study (Wiltshire *et al.,* 2014).

We used a range of 1.47 to 1.83 t CO_2e sequestered in soil per ha per year.

The mitigation potential at NUTS 2 level (kt CO_2e/y) is shown in Figure 10.

Figure 10: Mitigation potential at NUTS 2 level, kt CO_2e/y



Environmental co-benefits and risks of the MA

There are other environmental benefits from creating new woodland, hedgerows, woody buffer strips and planting trees, additional to the effect on GHG emissions. These benefits could include:

- reduced risks of soil erosion
- reduced risk of pollution of watercourses by run-off from farmland (riparian woodland)
- improved water infiltration and reduced risk of flooding (watershed management);
- improved biodiversity and habitat connectivity, depending on the species and diversity of tree/shrub species used and the subsequent management;
- greater structural diversity of farmland habitats and landscapes;
- benefits of wind speed reduction, cooler microclimate and shade (for livestock);
- more diverse soil microbial communities and improved soil structure.

There are also risks to the environment from implementing the action, and to GHG emissions as a result of the changes to production. These risks could include:

- production displacement from the afforested area of agricultural land leading to increased production elsewhere, possibly in regions where GHG emissions per tonne of crop or per livestock unit are greater than in the EU.
- negative effects on biodiversity in specific circumstances, for example if non-native tree species/genotypes are planted near semi-natural woodland habitats, or if existing valuable farmland habitats are converted to woodland (for example, species rich grassland manages as low-intensity pastures and meadows)

Both benefits and risks will vary considerably, depending on the scale, location and type of farmland on which afforestation takes place, the tree/shrub species used and the intensity and timescale of subsequent management.

Technological and socio-cultural barriers

The ‘crop rotation’ of woodland is far longer than that of agricultural crops, and is measured in decades, not years. It is therefore very important, for maintaining the GHG and other environmental benefits and for the long-term economic value of the woodland, that the tree species and genotypes are resilient to the effects of climate change, particularly the spread of tree pests and diseases. Further technological developments may be required, for example in selecting resistant genotypes and using species mixes rather than monocultures.

Although techniques of woodland creation are well known, whether by planting trees or by selecting from natural regeneration, many farmers may not have any experience of growing trees, especially in countries where there is no tradition of farmers also being forest owners, as there is in many northern Member States.

Costs/business benefits to land managers of implementing the MA at farm/forest level

Afforestation is a significant long-term change in the land use, taking land out of agricultural production altogether. The opportunity costs of creating woodland or planting trees or hedges depend on the agricultural potential of the newly wooded land. Farmers are likely to choose land of lower productivity in locations where woodland, trees and hedges could also bring agricultural benefits. Establishment and management costs of the woodland and hedging may include costs of specialist advice, machinery, contractors and fencing, in addition to the cost of the trees/shrubs. A study carried out in 2011 looked at the payment rates for a range of environmental actions in a selection of the 2007 to 2013 RDPs covering regions with different geographical, topographical and economic characteristics. Based on information from 11 RDPs, the average payment for afforestation of agricultural land was €1,976/ha (unpublished Annex to Hart *et al.,* 2011).

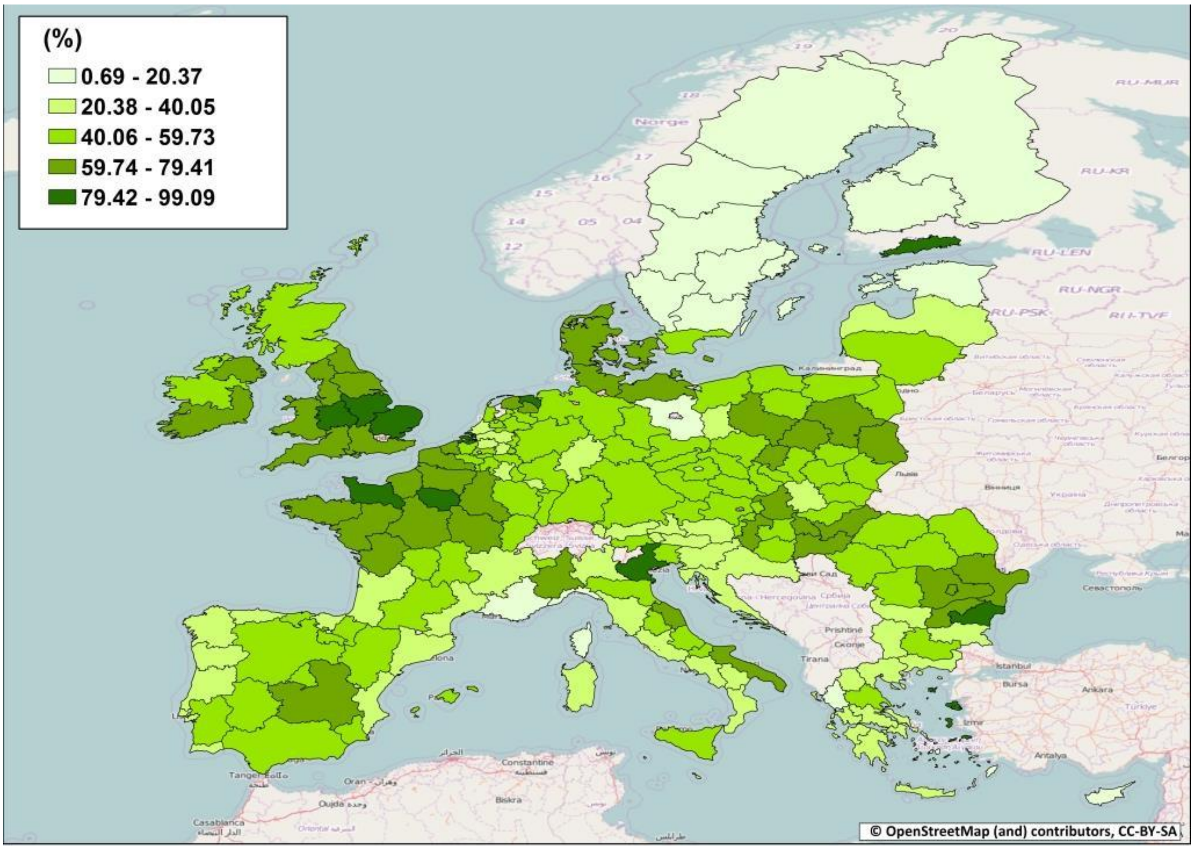
There is a significant time lag between the initial establishment costs and any income from the trees, but how long this is depends very much on the type of the species used and the objective of subsequent management. In addition to income from producing biomass (for wood pulp or energy generation) and timber for many different purposes, farmers may also locate and manage their woodlands for other agricultural and personal benefits such as livestock shelter, reduced soil erosion, provision of timber or woodfuel for use on the farm, or for hunting.

Farmers could choose to implement this climate mitigation action in the short-term (before 2020), but individual decisions will be influenced by the economic impact on the farm business and possibly other factors, such as permanent loss of eligibility for CAP direct payments on the afforested land.

Geographic relevance

Woodland planting is related to all agricultural area, except forest. The percentage of agricultural area by NUTS 2 level is shown in Figure 11. Geographic relevance is particularly low in Scandinavia where there is much forest and other non-agricultural land.

Figure 11: Land in agricultural production as a percentage of total area for each NUTS 2 region



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 12, Table 13 and Table 14.

Table 12: Summary of reporting issues for Afforestation

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes.
Is there a methodology that will show specific impact of the mitigation action? What is it?	Yes. The impact of afforestation can be reported in in inventories using a tier 1, 2 or 3 approach.
Categories	Land converted to Forestland
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Land converted to Forestland
Which Member States included this as a Key Category in their 2014 National Inventory Reports	22 Member States, AT,BG,DE,EE,ES,FI,FR,HR,HU,IE,IT,LT,LU,LV,NL,PL, PT,RO,SE,SI,SK,UK
Tiers used	Tier 1: 4 MSs - AT,CZ,EE,LT Tier 2: 14 MSs - BE,BG,ES,FI,FR,HR,HU,IT,LU,LV,NL,PL,SI,SK Tier 3: 3 MSs - IE,SE,UK Not specified: 7
Limitations of the Inventory reporting structure	No major limitation with the methodology. Some member states have not detailed the method used. Providing the correct activity data is accessible there is species specific information in the IPCC guidance provided. Care needs to be taken to ensure that double counting is not occurring because of mixing and matching activity data.

Table 13: Summary of reporting issues for Reforestation

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes.
Is there a methodology that will show specific impact of the mitigation action? What is it?	Yes. The impact of afforestation can be reported in in inventories using a tier 1, 2 or 3 approach.
Categories	Land converted to Forestland (based on the assumption that the land has been in other land use since the previous forest was cleared within the last 50 years) note differentiation between afforestation and reforestation
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Land converted to Forestland
Which Member States included this as a Key Category in their 2014 National Inventory Reports	22 Member States, AT,BG,DE,EE,ES,FI,FR,HR,HU,IE,IT,LT,LU,LV,NL, PL,PT,RO,SE,SI,SK,UK
Tiers used	Tier 1: 4 MSs - AT,CZ,EE,LT Tier 2: 14 MSs - BE,BG,ES,FI,FR,HR,HU,IT,LU,LV,NL,PL,SI,SK Tier 3: 3 MSs - IE,SE,UK Not specified: 7
Limitations of the Inventory reporting structure	No major limitation with the methodology. Some member states have not detailed the method used. Providing the correct activity data is accessible there is species specific information in the IPCC guidance provided.

	Care needs to be taken to ensure that double counting is not occurring because of mixing and matching activity data.

Table 14: Summary of reporting issues for Shelterbelts, hedgerows, woody buffer strips, and in-field trees

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	No
Is there a methodology that will show specific impact of the mitigation action? What is it?	No. There is not an obvious option. The methodology does not specifically account for boundary features inclusion of hedge rows and trees. From our analysis of NIRs and methodologies there is not an obvious place in categories that will account for this type of activity. In some respects this action is similar to the agroforestry action. Should the action be adopted on an agroforestry scale then the same methodological approach could apply. Shelter belts and in field trees may be picked up in land use change categories
Categories	Land converted to Forestland Cropland Remaining Cropland
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	N/A
Which Member States included this as a Key Category in their 2014 National Inventory Reports	N/A
Tiers used	N/A
Limitations of the Inventory reporting structure	As stated earlier, there is not clear method to account for this level of activity

Policy measures that could be or have been used to encourage implementation of the MA in the EU

RDP support for afforestation of farmland and of other land is one of the long established environmental land management measures and, in the case of agricultural land may include compensation for loss of CAP direct payments on the land in the early years of establishing the woodland. In the 2007-13 RDPs the measure for **afforestation of agricultural land (221)** was programmed in 64 of the 88 RDPs. In the first six years of implementation this supported the establishment of almost 260,500 of hectares of new woodland, achieving 46% of the target uptake area for EU-27. By 2013 the total public expenditure on this measure in EU-27 was €2.1 billion, 79.6% of the programmed expenditure. The measure for **afforestation of non-agricultural land (223)** was programmed in 35 of the 88 RDPs and in the first six years of implementation supported the establishment of almost 80,000 of hectares of new woodland (mainly in Spain, the UK, Lithuania and Latvia) achieving 43% of the target uptake area for EU-27. By 2013 total public expenditure on this measure in EU-27 was €0.19 billion, 48% of the programmed amount[18]. Preliminary information for the 2015 to 2020 Programmes indicates that 19 Member States may provide around €1.6 billion of RDP support for establishment of more than 500,000 ha of forests and wooded areasOther Member States (e.g. Ireland) have chosen not to use the RDP afforestation measures and instead they plan to use national resources to support afforestation, in line with the new Forestry State Aid Guidelines.

From 2015, under the CAP greening requirements, EFAs may be areas of woodland created with RDP support (in either 2007-13 or 2014-20) or national support which meets the RDP environmental requirements of afforestation. Fourteen of the EU-28 Member States have chosen to offer farmers this option (for details see Annex 5 Table 1).

The EAFRD measure for non-productive investments (216) has been used by the UK and possibly other Member States to support planting trees in groups or fields and for hedge planting, but reports and analyses of the 2007 to 2013 RDPs at measure level do not identify these specific uses of this measure and no summary information is available on the 2015 to 2020 RDPs.

Where it is appropriate to promote this action, and the requirements for verification and control can be met, the relevant CAP measures could include:

- Pillar 1 greening requirements for EFAs, which can be areas of woodland created with RDP or equivalent national support, or new hedges, trees in lines or groups and isolated trees on or adjacent to arable land
- RDP support for non-productive investments linked to the achievement of agri-environment-climate objectives (M4.4) for planting individual trees, groups of trees and hedges
- RDP support for afforestation and creation of woodland on both agricultural and non-agricultural land (M8.1)

References

Benítez-Ponce, P.C., McCallum, I., Obersteiner, M. and Yamagata, Y. (2007) Global potential for carbon sequestration: geographical distribution, country risk and policy implications, *Ecological Economics*, 60, 572-583.

Bhogal, A., Nicholson, F.A., Rollett, A and Chambers, B.J (2009) Best Practice for Managing Soil Organic Matter in Agriculture - Manual of Methods for 'Lowland' Agriculture, Prepared as part of Defra project SP08016.

Eisbrenner, K. and Gilbert, A. (2009) Land use, land use change and forestry. Sectoral Emission Reduction Potentials and Economic Costs for Climate Change (SERPEC-CC).

Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu, J.L., Lasorella, M.V. and Longhitano, D. (2014). Mainstreaming climate change into rural development policy post 2013. Final report. Ecologic Institute, Berlin.

[18] Source: ENRD Progress Snapshot 2013 (updated May 2014) Measure 221 – First afforestation of agricultural land (data on financial implementation up to 2013, output data up to 2012) http://enrd.ec.europa.eu/enrd-static/app_templates/enrd_assets/pdf/measure-information-sheets/C_Infosheet_221.pdf

Hart K, Baldock D, Tucker G, Allen B, Calatrava J, Black H, Newman S, Baulcomb C, McCracken D, Gantioler S (2011) Costing the Environmental Needs Related to Rural Land Management, Report Prepared for DG Environment, Contract No ENV.F.1/ETU/2010/0019r. Institute for European Environmental Policy, London

IPCC (2007) Assessment Report 4, Working Group III Report "Mitigation of Climate Change" Chapter 1, 8 and 9

Posthumus, H., Deeks, L.K., Rickson, R.J and Quinton, J.N (2013) Costs and benefits of erosion control in the UK. *Soil Use and Management*. DOI: 10.1111/sum.12057

Sathaye, J.A., Makundi, W., Dale, L., Chan, P. and Andrasko, K. (2007) GHG mitigation potential, costs and benefits in global forests: A dynamic partial equilibrium approach, *Energy Journal*, Special Issue 3, 127-172.

Sohngen, B. and Sedjo, R. (2006) Carbon sequestration costs in global forests, *Energy Journal*, Special Issue, 109-126.

Standing Forestry Committee Ad Hoc Working Group III on Climate Change and Forestry, SFC, (2010) Climate change and forestry. Report to the Standing Forestry Committee.

Wiltshire, J., Martineau, H., Webb, J., Shamier, N., Bell, H., Rees, B. (2014) Assessment of the Effectiveness, Impact and Cost of Measures to Protect Soils, Defra project SP1313.

Preventing deforestation and removal of farmland trees

Description

Forest or woodland management may contribute to GHG mitigation through prevention of deforestation and forest degradation.

Mode of action

Deforestation and forest degradation release stored carbon in soil and biomass.

Mitigation potential

Influencing factors

Deforestation and forest degradation in developing countries account for almost 20% of global CO_2 emissions. Hence, helping developing countries to reduce deforestation and forest degradation will be essential if dangerous climate change is to be averted. However, deforestation is not a problem in the EU (SFC, 2010).

Table 15: Summary of influencing factors for woodland management: preventing deforestation and removal of farmland trees

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Woodland and forestry
Which soil types is this MA relevant to?	All
Which climatic zones is this MA relevant to?	All

Values

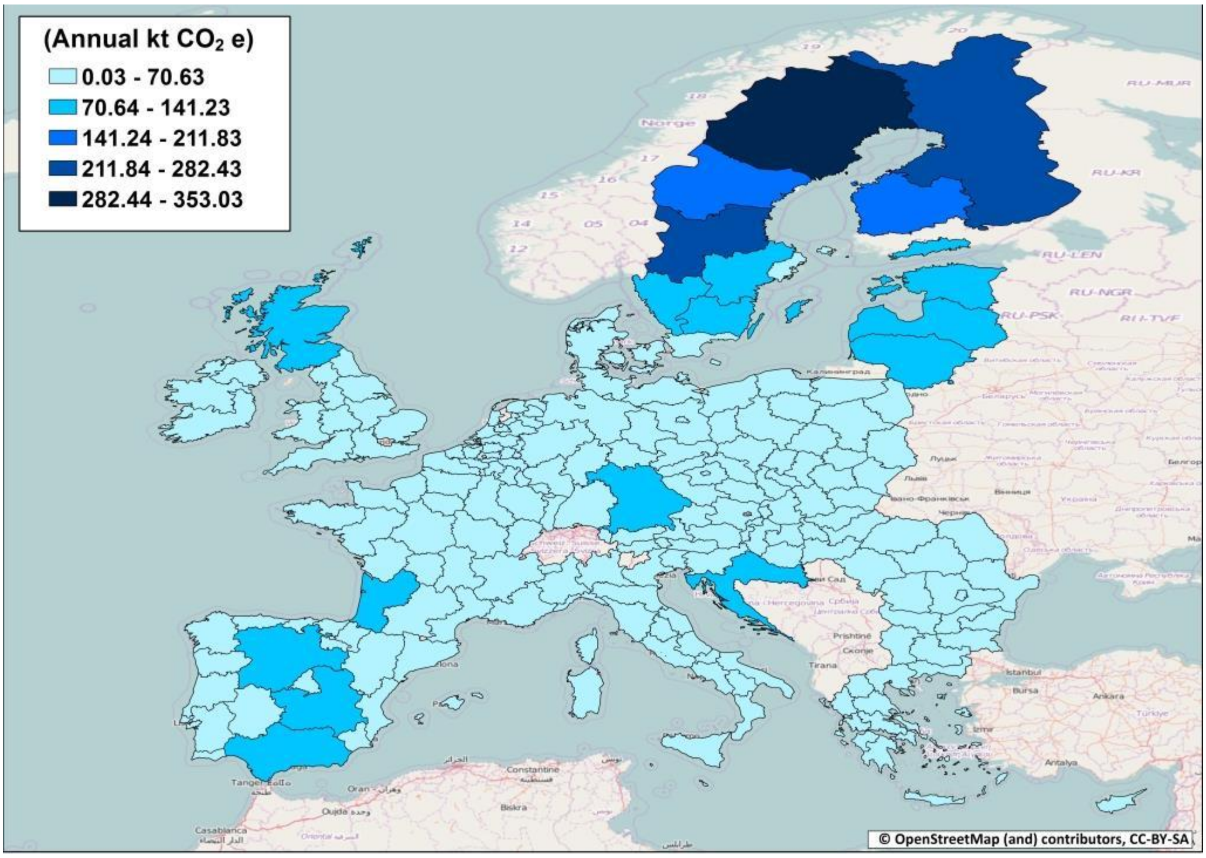
The IPCC estimates the mitigation potential of preventing deforestation in Europe as only 10 Mt CO_2 / year under a cost of 100 US $ / t CO_2 (IPCC, 2007). The figure is based on an averaged output from three global forest sector models that provide estimates for all regions of the world (Sohngen and Sedjo, 2006; Sayathe *et al.,* 2007; Benitez-Ponce *et al.,* 2007).

The carbon sequestration potentials below are estimates of the additional carbon sequestered if deforestation is prevented. The smaller estimate is for Boreal woodlands which are slow growing. Maintaining existing woodland will not sequester carbon indefinitely as the soil's capacity for carbon will become saturated. These estimates are for up to 2030. The estimates of C sequestration cited below were derived from the CLIMSOIL report.

We used a range of 0.73 to 7.3 t CO_2e sequestered in soil per ha per year.

The mitigation potential at NUTS 2 level (kt CO_2e/y) is shown in Figure 12.

Figure 12: Mitigation potential at NUTS 2 level, kt CO_2e/y



Environmental co-benefits and risks of the MA

There are other environmental benefits of this action, additional to the effect on GHG emissions but these benefits depend very much not only on retaining the woodland, trees or hedges but if and how these are managed, and what are the objectives of management. The benefits are similar to those for afforestation and include:

- reduced risks of soil erosion
- reduced risk of pollution of watercourses by run-off from farmland (riparian woodland)
- improved water infiltration and reduced risk of flooding (watershed management);
- biodiversity and habitat connectivity, depending on the management of the woodland;
- structural diversity of farmland habitats and landscapes;
- benefits of wind speed reduction, cooler microclimate and shade (for livestock);
- more diverse soil microbial communities and improved soil structure, depending on the management of the woodland

There are few risks to the environment simply from preventing deforestation. However in some cases where forest plantations have been created on drained wet peatland, the most appropriate environmental management may be deforestation and rewetting the peatland (although this may initially increase methane emissions, in the longer term the net carbon capture is likely to outweigh this effect).

Technological and socio-cultural barriers

There are unlikely to be technological barriers or socio-cultural barriers to preventing deforestation in the EU.

Costs/business benefits to land managers of implementing the MA at farm/forest level

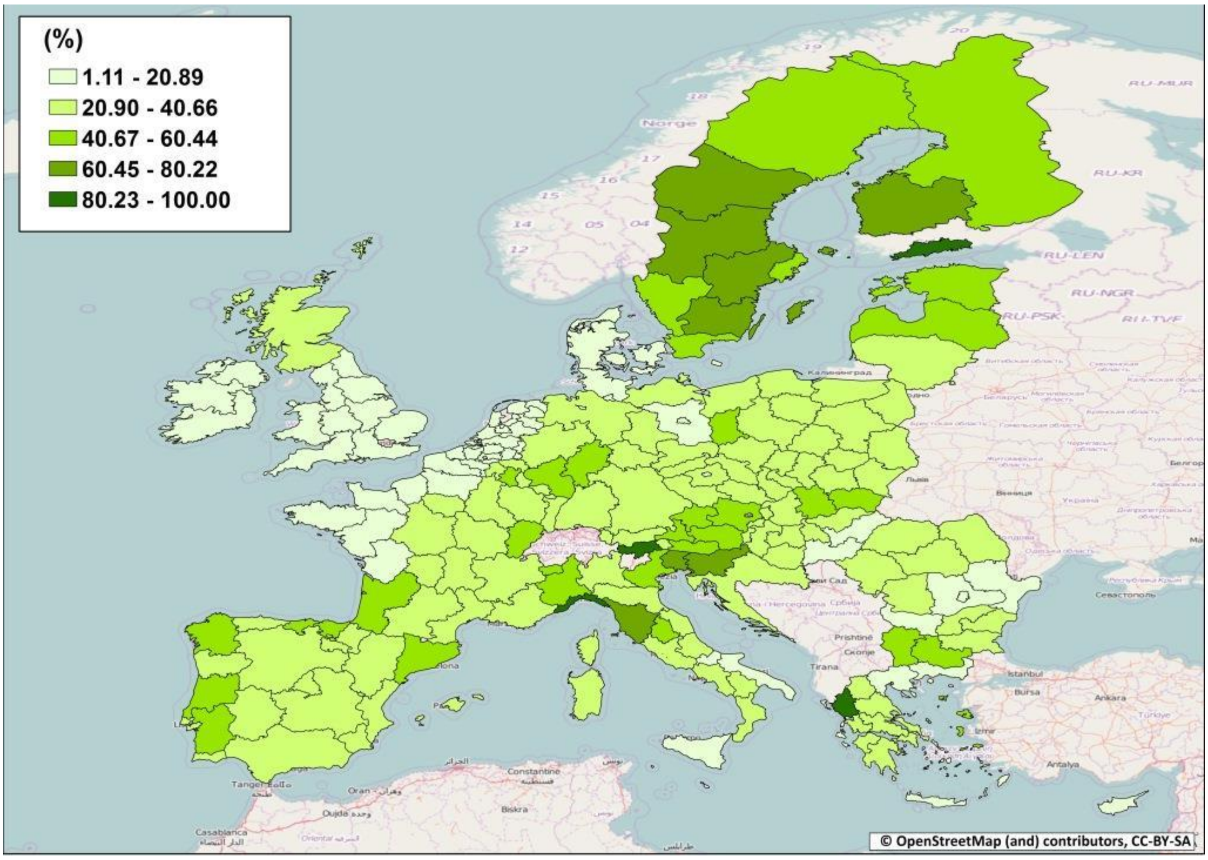
Theoretically there are opportunity costs of not using the land for other, more profitable purposes such as tourist development or possibly agriculture, but in practice the removal of woodland is controlled in many EU countries through national or regional legislation which may prohibit removal and/or require replanting of woodland (and in some cases individual trees) except where this is required to control tree pests and diseases. It is important to note that legislation protecting forests, trees and hedges from removal may not require any active management of the trees.

Farmers will already be implementing this action to the extent required by local or national regulations, but any decision to retain trees or hedges not protected by legislation could be taken in the short-term (before 2020).

Geographic relevance

Woodland management: preventing deforestation is related to woodland area. The percentage of woodland area at NUTS 2 level is shown in Figure 13.

Figure 13: Woodland area as a percentage of total area for each NUTS 2 region



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 16.

Table 16: Summary of reporting issues for woodland management: preventing deforestation and removal of farmland trees

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes. As a prevention action, the impact is based on the alternative deforestation scenario. So the impact is assesses compared to the counterfactual scenario.
Is there a methodology that will show specific impact of the mitigation action? What is it?	No. 'Greenhouse gas inventory for *Forest Land Remaining Forest Land* (FF) involves estimation of changes in carbon stock from five carbon pools (i.e., above-ground biomass, below ground biomass, dead wood, litter, and soil organic matter), as well as emissions of non-CO_2 gases.' The methodology does not provide assessment of the impact of actions that prevent deforestation. It would require analysis of the deforestation avoided to record the impact.
Categories	Forestland remaining Forestland
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Forestland remaining Forestland
Which Member States included this as a Key Category in their 2014 National Inventory Reports	25 MSs AT,BG,CZ,DE,DK,EE,EL,ES,FI,FR,HR,HU,IT,LT,LU,LV,MT,NL,PL,PT,RO, SE,SI,SK,UK
Tiers used	Tier 1: 9 MSs - BG,CZ,EE,ES,HR,LT,LU,MT,SK Tier 2: 11 MSs - BE,DE,EL,FI,FR,HU,LV,NL,PL,RO,SE Tier 3: 5 MSs - AT,IE,IT,SI,UK Not specified: 3
Limitations of the Inventory reporting structure	Preventing deforestation will have an obvious impact on the inventory but identifying the impact will be difficult within the methodology provided as it requires the inventory to state how much deforestation has been avoided as a result of an action.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

For the 2014 to 2020 period Member States can choose to use both cross-compliance and greening payments in a way that helps to protect 'woody' landscape features on farmland. In defining the GAEC 7 cross-compliance standard for landscape features Member States can require farmers to retain hedges, trees in lines or groups and isolated trees (although there is no obligation for farmers to actively maintain these features through appropriate management). Member States can also choose to include the same types of 'woody' landscape features in the list of EFA options for farmers, whether or not these are included in the GAEC 7 standard.

All but eight of the EU-28 Member States have chosen to include at least one type of 'woody' feature their GAEC 7 standards and/or EFA landscape options (the exceptions are Austria, Cyprus, Denmark, Finland, Lithuania, Portugal, Slovenia and Spain). For more details please see Annex 5, Table 2.

The relevant CAP measures to prevent the removal of woodland, trees and hedges on farmland are:

- GAEC 7 Retention of landscape features, including where appropriate, hedges, ponds, ditches, trees in line, in group or isolated, field margins and terraces, and including a ban on cutting hedges and trees during the bird breeding and rearing season;
- SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs;
- Pillar 1 greening requirements for EFAs, which can be existing hedges, trees in lines or groups and isolated trees.

References

Benítez-Ponce, P.C., McCallum, I., Obersteiner, M. and Yamagata, Y. (2007) Global potential for carbon sequestration: geographical distribution, country risk and policy implications, *Ecological Economics*, 60, 572-583.

IPCC (2007) Assessment Report 4, Working Group III Report "Mitigation of Climate Change" Chapter 1, 8 and 9

Sathaye, J.A., Makundi, W., Dale, L., Chan, P. and Andrasko, K. (2007) GHG mitigation potential, costs and benefits in global forests: A dynamic partial equilibrium approach, *Energy Journal*, Special Issue 3, 127-172.

Sohngen, B. and Sedjo, R. (2006) Carbon sequestration costs in global forests, *Energy Journal*, Special Issue, 109-126.

Standing Forestry Committee Ad Hoc Working Group III on Climate Change and Forestry, SFC, (2010) Climate change and forestry. Report to the Standing Forestry Committee.

Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land

Description

Forest management activities influence on-site carbon stores, fluxes, and sequestration, both positively and negatively, either directly, for instance, by maintaining forest carbon stocks through forest conservation, transferring carbon from ‘‘live growing stock’’ to the ‘‘product’’ pools (e.g. thinning, final harvesting), or indirectly by altering growth conditions of trees (e.g. liming, fertilizing). The effects can be instantaneous (e.g. thinning) or evolve slowly (e.g. fertilisation). Activities may: affect the current stand (e.g. thinning regime) or future stands (e.g. regeneration); or be transient (e.g. minimizing site preparation, planting).

Mode of action

Forestry contributes to climate change mitigation by: conserving and increasing carbon stocks in forests (including above- and below-ground biomass, deadwood, litter, and soil); producing renewable materials that can be used to substitute fossil fuels and materials that are energy-intensive to produce; and storing carbon in harvested wood products.

Mitigation potential

Influencing factors

The capacity of forests to store carbon varies strongly between regions in Europe. While young forests have initially high carbon sequestration rates, these decline in ageing forests. Mature forests may eventually reach an equilibrium at which relatively little further sequestration takes place. Therefore, the mitigation potential from extensification of forest management has limits (SFC, 2010). In Mediterranean countries in particular, the risk of forest fires should also be taken into account in the mitigation strategies and choice of silvicultural methods, for example the length of rotations and the use of grazed firebreaks.

Table 17: Summary of influencing factors for management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Woodland and Forestry
Which soil types is this MA relevant to?	All
Which climatic zones is this MA relevant to?	All

Values

Frelih-Larsen *et al.,* (2014) identified from the literature (Bhogal *et al.,* 2009; Posthumus *et al.,* 2013) that with regard to the carbon loss avoided due to reduced erosion and the increase in carbon stored:

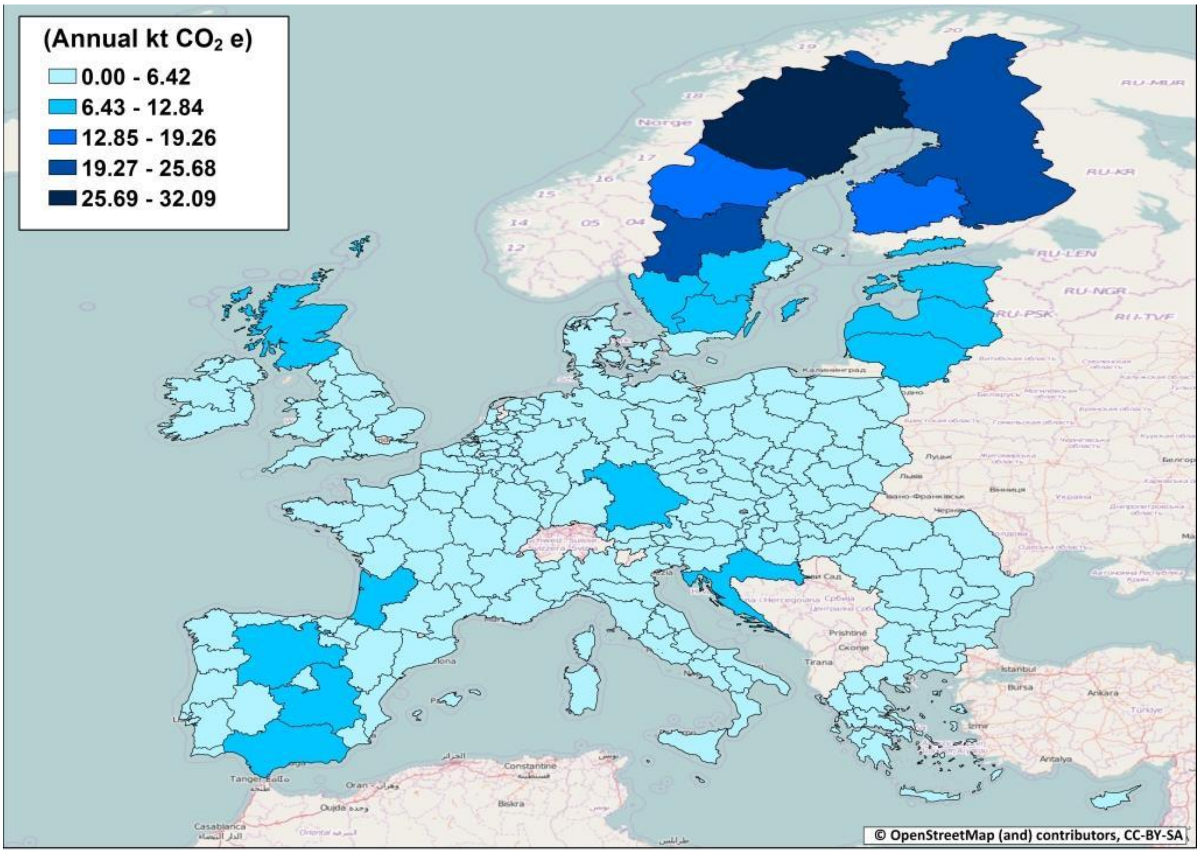
- Hedgerows have a small effect in grasslands and a moderate effect in arable fields.
- Shelterbelts have an impact of +14 kg C/ha/yr.

For this potential mitigation action we made the assessment of EU-wide mitigation based on the introduction of shelterbelts as this option had the best documented report of abatement potential, albeit data for this option were limited and insufficient to suggest a robust range. The values below were taken from a recent UK study (Wiltshire *et al.,* 2014).

We used a value of 0.37 t CO_2e sequestered in soil per ha per year.

The mitigation potential at NUTS 2 level (kt CO_2e/y) is shown in Figure 14.

Figure 14: Mitigation potential at NUTS 2 level, kt CO_2e/y



Environmental co-benefits and risks of the MA

There are other environmental benefits of this action, additional to the effect on GHG emissions but these benefits depend how the woodland, trees and hedges are managed, and what are the objectives of management. The benefits are similar to those for afforestation and include

- reduced risks of soil erosion;
- reduced fire risk in drier areas (compared to unmanaged woodland);
- reduced risk of pollution of watercourses by run-off from farmland (riparian woodland);
- improved water infiltration and reduced risk of flooding (watershed management);
- biodiversity and habitat connectivity, depending on the management of the woodland, trees and hedges;
- maintaining structural diversity of farmland habitats and landscapes;
- benefits of wind speed reduction, cooler microclimate and shade (for livestock);
- more diverse soil microbial communities and improved soil structure, depending on the management.

There are also risks to the environment from changing current management in a way that reduces existing benefits. These risks could include:

- reducing the benefits for biodiversity, water quality and soils by changes in management (for example, replanting native woodland trees or woodland with exotic species, clear felling instead of continuous cover management, removing all dead wood and waste material from forest operations).

Technological and socio-cultural barriers

There are unlikely to be technological barriers to woodland management but owners may need specialist advice or machinery to manage valuable woodland habitats or protected woodlands. There may be public concern about some management operations in woodlands that are perceived to be of aesthetic or cultural importance.

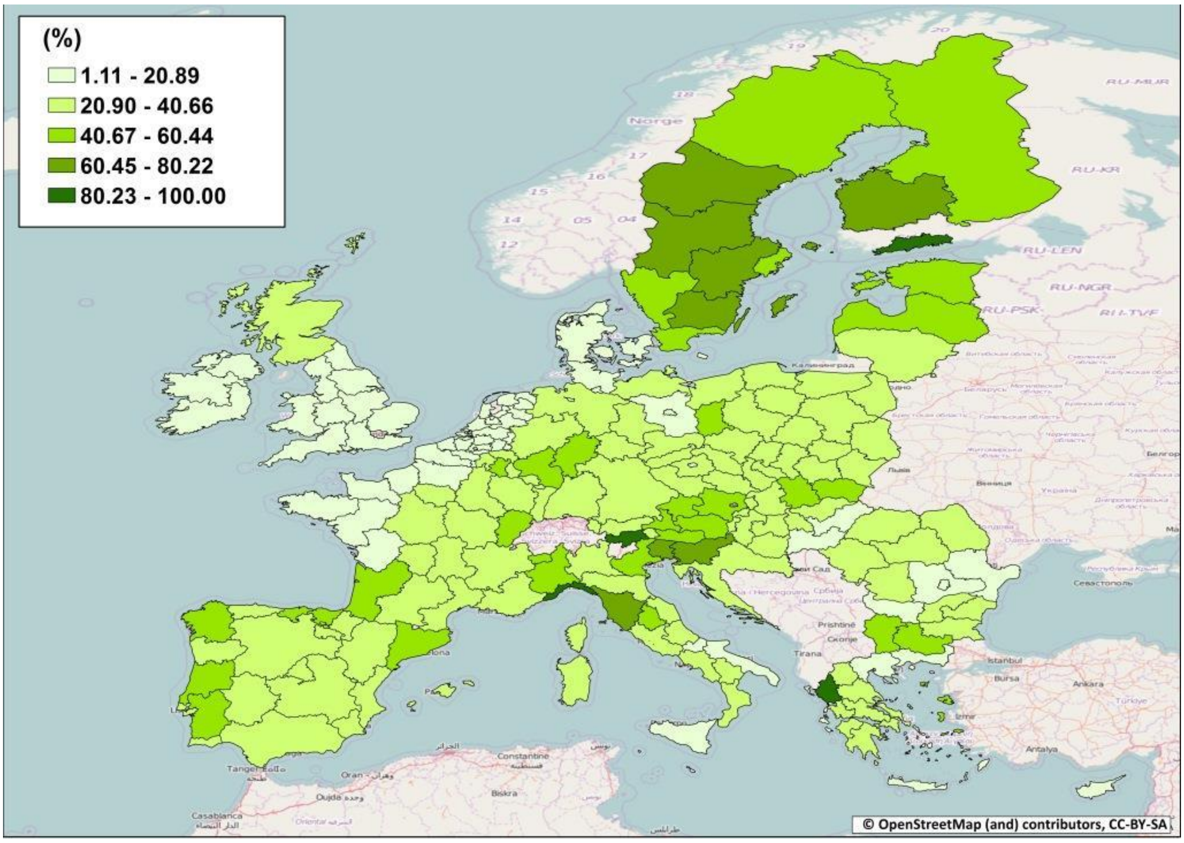
Costs/business benefits to land managers of implementing the MA at farm/forest level

The costs of managing existing woodland, trees and hedges will vary depending on the management objectives, the type and frequency of the work, the extent of previous neglect and the need for restorative work. Similarly, any income from harvesting will vary in amount and frequency from one woodland to another, and will be influenced by the costs of extraction, transport to processors and market prices.

Geographic relevance

Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land is related to woodland and agricultural area (Figure 15). Relevant land use occurs widely across the EU.

Figure 15: Land in woodland and arable production as a percentage of total area for each NUTS 2 region



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 18.

Table 18: Summary of reporting issues for management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes. Only if detailed activities relating to management practices are collected. We did not find examples where this was being done in any NIR's. Specific actions of woodland management relating to farm woodland and hedgerows not collected.
Is there a methodology that will show specific impact of the mitigation action? What is it?	Yes. In theory a tier 3 approach should allow specific management activities to be identified and reported on. Tier 1 & 2 are general approaches and will not account for detailed management practices.
Categories	Forestland remaining Forestland
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Forestland remaining Forestland
Which Member States included this as a Key Category in their 2014 National Inventory Reports	25 AT,BG,CZ,DE,DK,EE,EL,ES,FI,FR,HR,HU,IT,LT,LU,LV,MT,NL,PL,PT,RO,SE,SI,SK,UK
Tiers used	Tier 1: 9 MSs - BG,CZ,EE,ES,HR,LT,LU,MT,SK Tier 2: 11 MSs - BE,DE,EL,FI,FR,HU,LV,NL,PL,RO,SE Tier 3: 5 MSs - AT,IE,IT,SI,UK Not specified: 3
Limitations of the Inventory reporting structure	There is likely to be a detectable change if the activity can be accurately captured.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

The following four measures were used to support woodland management in the 2007-13 RDPs.

The measure for **forest Natura 2000 payments (224)** was programmed in 35 of the 88 RDPs and in the first six years of implementation 142,00 hectares of forest in Natura 2000 areas received payments (mainly in Estonia, Latvia, Slovakia, Belgium and Germany) achieving 39% of the target uptake area for EU-27. By 2013 total public expenditure on this measure in EU-27 was €0.049 billion, 50% of the programmed amount. The **forest-environment measure (225**), providing annual payments for managing woodland for environment and climate services and forest conservation, was programmed in 28 of the 88 RDPs. In the first six years of implementation around 281,000 of hectares received support (mainly in the UK, Germany and Italy) achieving 18% of the target uptake area for EU-27. By 2013 the total public expenditure on this measure in EU-27 was €0.086 billion, 36% of the programmed amount. The measure **supporting the prevention and restoration of damage to forests by fires and natural disasters (226)** was programmed in 58 of the 88 RDPs and in the first six years of implementation supported 52,100 preventative actions (mainly in Spain and Austria) achieving 48% of the target for EU-27. By 2013 the total public expenditure on this measure in EU-27 was €1.6 billion, 67% of the programmed amount. The measure **for environmental investment in forests (227)** was programmed in 70 of the 88 RDPs and in the first six years of implementation supported investments by than 75,000 forest holders, 41% of the target uptake for EU-27. By 2013 the total public expenditure on this measure in EU-27 was €0.721 billion, 58% of the programmed amount, most of it in Germany, Spain, Italy, the UK and Portugal[19].

A further two measures, for agri-environment (214) and non-productive investments (216) have been used to support management and restoration work on farmland hedges and trees in some Member States, but reports and analyses of the 2007-13 RDPs at measure level do not identify specific uses of these measures and no summary information is available for the 2015-2020 RDPs.

Where it is appropriate to promote this action the relevant RDP measures could include:

- support for non-productive investments linked to the achievement of agri-environment-climate objectives (M4.4) for restoration of farmland trees and hedges;
- agri-environment-climate payments, as equivalence for EFAs or separately (M10.1) for management of farmland trees and hedges;
- support for prevention of damage to forests from forest fires and natural disasters and catastrophic events (M8.3)
- support for restoration of damage to forests from forest fires and natural disasters and catastrophic events (M8.4)
- support for investments improving the resilience and environmental value of forest ecosystems (M8.5)
- compensation payment for Natura 2000 forest areas (M12.2)
- payment for forest-environmental and climate commitments (M15.1)
- support for the conservation and promotion of forest genetic resources (M15.2)

[19] Source: ENRD Progress Snapshot 2013 (updated May 2014) Measure 221 – First afforestation of agricultural land (data on financial implementation up to 2013, output data up to 2012) http://enrd.ec.europa.eu/enrd-static/app_templates/enrd_assets/pdf/measure-information-sheets/C_Infosheet_221.pdf

- support for joint action undertaken with a view to mitigating or adapting to climate change and for joint approaches to environmental projects and ongoing environmental practices (M16.5)
- support for drawing up of forest management plans or equivalent instruments (M16.8)

References

Bhogal, A., Nicholson, F.A., Rollett, A and Chambers, B.J (2009) Best Practice for Managing Soil Organic Matter in Agriculture - Manual of Methods for 'Lowland' Agriculture, Prepared as part of Defra project SP08016.

Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu, J.L., Lasorella, M.V., Longhitano, D. (2014). Mainstreaming climate change into rural development policy post 2013. Final report. Ecologic Institute, Berlin.

Posthumus, H., Deeks, L.K., Rickson, R.J. and Quinton, J.N. (2013) Costs and benefits of erosion control in the UK. *Soil Use and Management*. DOI: 10.1111/sum.12057

Standing Forestry Committee Ad Hoc Working Group III on Climate Change and Forestry, SFC, (2010) Climate change and forestry. Report to the Standing Forestry Committee

Wiltshire, J., Martineau, H., Webb, J., Shamier, N., Bell, H., Rees, B. (2014) Assessment of the Effectiveness, Impact and Cost of Measures to Protect Soils, Defra project SP1313.

Reduced tillage

Description

Reduced tillage is used to describe all non-plough based cultivation practices. There are many approaches to reduced tillage. The common factors are that reduced tillage does not completely invert the soil and less energy is required to carry out cultivation.

Mode of action

This mitigation action is considered with respect to its potential for saving energy used for soil cultivation, and sequestering carbon (C) in the soil. Only where crop yields are increased by the introduction of reduced tillage is C sequestration likely to occur.

There may also be changes in emissions of N_2O from soil, but this is not considered further because of a lack of evidence.

Mitigation potential

Influencing factors

Table 19: Summary of influencing factors for reduced tillage

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Arable (cropland) systems, and any other systems with annual crops (e.g. field vegetables).
Which soil types is this MA relevant to?	Light (i.e. course) soils and soils high in $CaCO_3$.
Which climatic zones is this MA relevant to?	Any, but especially useful in dry regions because there is some conservation of soil water.

Values

In a meta-analysis of experiments carried out in Europe, Van den Putte *et al.,* (2010) reported yield reductions of 4% for winter cereals and 13% for maize, but no impact on other crops. However, the large range of cultivations that can be considered as reduced tillage makes a balanced comparison of C sequestration, between reduced tillage and conventional tillage, very difficult. The lack of consistent evidence to indicate that reduced tillage sequesters C in soils leads us to recommend that this mitigation potential by this mode of action is not considered further, and a value of zero is used.

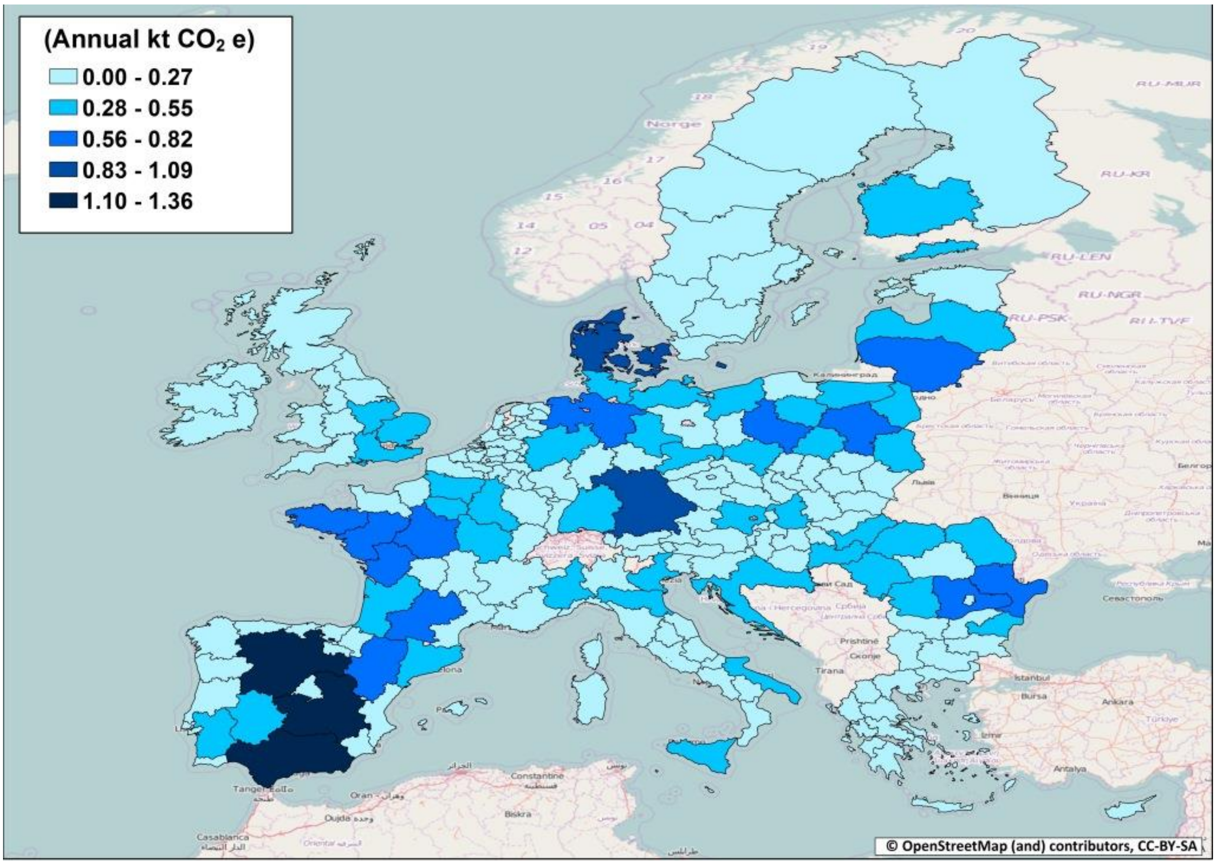
However, CO_2 emissions from fuel consumption will be reduced due to the decreased need for cultivation. Estimates of reduced fuel use are taken from the UK MACC for farm energy consumption, and expert knowledge of field operations in arable crops.

We used a range of 2.5 to 7.5% of the fuel used in field operations; 76 L of fuel per ha (Nix, 2013), and 3.144 kg CO_2 per L.

The calculated mitigation potential range was 0.0059 to 0.0180 t CO_2e /ha/y.

The mitigation potential at NUTS 2 level (kt CO_2e/y) is shown in Figure 16.

Figure 16: Mitigation potential at NUTS 2 level, kt CO_2e/y



Environmental co-benefits and risks of the MA

There other environmental benefits of this action, additional to the effect on GHG emissions. These benefits could include:

- less risk of soil erosion by wind or water, because soil exposure is significantly reduced.

There are also risks to the environment from implementing the action and to GHG emissions as a result of the changes to production. These risks could include:

- increased use of herbicides to kill weeds that would otherwise be controlled by ploughing and increased application of slug pellets;

- production displacement if zero tillage is adopted in regions or cropping systems in which yield is reduced (Van den Putte *et al.,* 2010), leading to increased production elsewhere, possibly in regions where GHG emissions per tonne of crop produced are greater than in the EU.

Technological and socio-cultural barriers

Reduced tillage is already used in a number of Member States, the techniques are well understood and a variety of mechanical cultivation options are available. There are no known socio-cultural barriers to uptake of this climate mitigation action.

Costs/business benefits to land managers of implementing the MA at farm/forest level

Introducing reduced tillage will have an effect on the cropping system of the farm as a whole and maybe more difficult for farmers who have manure to dispose of.

Regional differences in the effects on crop yields, weeds and soil-borne plant pests and diseases will affect the balance of costs and savings for the farmer. Although costs of tillage will be lower, crop protection costs may rise if there is a need for increased use of herbicides to kill weeds that would otherwise be controlled by ploughing increased application of slug pellets, or of fungicides to control plant disease carried from crop residues left on the soil surface.

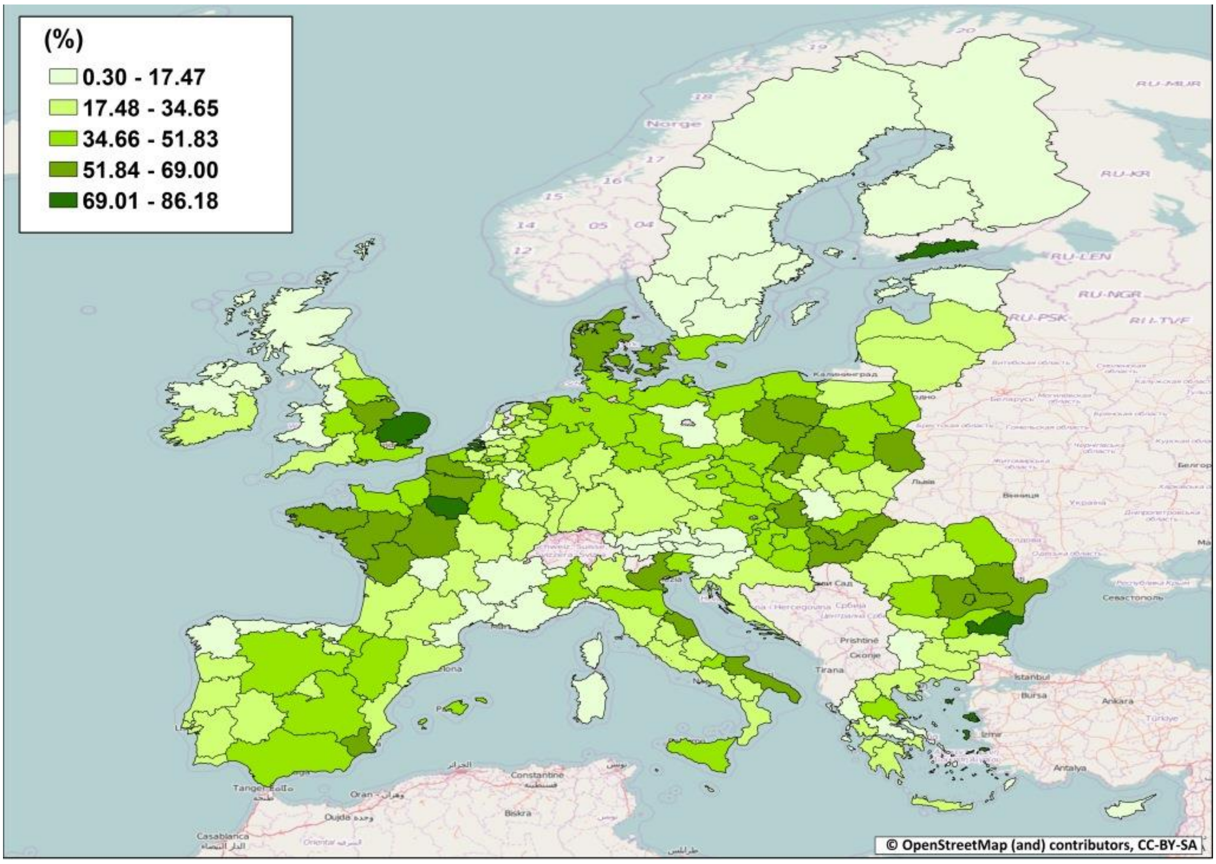
Individual studies from a few Member States provides a snapshot of costs but cannot be extrapolated to other regions e.g. one study In Poland found that reduced tillage yields almost the same profit as conventional tillage, because the lower financial return from the crop was compensated by reduced fuel use and (although not included in the financial evaluation) by reduced labour needs. There was no additional need for crop protection (Pronk *et al.,* 2015).

Farmers could choose to implement this climate mitigation action in the short-term (before 2020), but individual decisions will be influenced by the economic impact on the farm business and possibly other factors.

Geographic relevance

Reduced tillage can take place on arable land. The percentage of land currently in arable production systems, by NUTS 2 areas, is shown in Figure 17.

Figure 17: Land in arable production as a percentage of total area for each NUTS 2 region



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 20.

Table 20: Summary of reporting issues for reduced tillage

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes There are several potential mechanisms through which this action may mitigate GHG emissions, including change in soil organic carbon content and saving in energy for soil cultivations. The latter will result in a reduction in emissions estimated by a national inventory; other mechanisms may or may not influence the national inventories because of availability of activity data.
Is there a methodology that will show specific impact of the mitigation action? What is it?	Yes For soil carbon stock change: Refer to 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Vol 4, Ch 5 (cropland), 5.17, section 5.2.3.2, Table 5.5, stock change factors. Tier 1: The effect of the Mitigation Action is detectable, divided into pools: biomass, dead OM, soil carbon. Uses default figures. Tier 2: Relies on some country-specific estimates of the biomass in initial and final land uses rather than the defaults, as in Tier 1. Includes transfer between carbon pools, which changes the emissions total. Tier 3: Increases the accuracy but also has increased costs. Requires countries to have country-specific emission factors, and substantial national data. For CO_2 emissions from energy use: Vol 2, Ch 3, Section 3.3. Tiers 1, 2 and 3 can all be used; the accuracy increases with tier. Agriculture is not necessarily disaggregated from other off-road use of energy.
Categories	Cropland remaining Cropland Energy, fuel combustion, other sectors
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Cropland remaining Cropland Public Electricity and Heat Production Other Transportation
Which Member States included this	Cropland remaining Cropland 23 MSs:

as a Key Category in their 2014 National Inventory Reports	AT,BE,BG,CZ,DE,DK,EE,EL,ES,FI,FR,HR,HU,IT,LT,LU,LV,PL,RO,SE, SI,SK,UK Public Electricity and Heat Production 25 MSs: AT,BE,BG,CY,CZ,DE,EE,EL,ES,FI,FR,IE,IT,LT,LU,LV,MT,NL,PL,PT,RO, SE,SI,SK,UK Other Transportation 11 MSs: AT,BG,DE,ES,FI,FR,HU,IE,IT,LT,LU
Tiers used	Cropland remaining Cropland Tier 1: 16 MSs BE,BG,CZ,DE,EE,EL,FI,IE,IT,LU,LV,MT,PL,RO,SI,SK Tier 2: 4 MSs AT,ES,FR,HU Tier 3: 2 MSs ,SE,UK Not specified or not applicable: 6 MSs Public Electricity and Heat Production Tier 1: 9 MSs BE,DE,DK,EE,HR,HU,LT,NL,RO Tier 2: 11 MSsAT,BG,CY,EL,FR,LU,LV,PT,SE,SK,UK Tier 3: 5 MSs CZ,FI,IE,IT,SI Not specified or not applicable: 3 MS Other transportation Tier 1: 16 MSsBE,CY,DE,DK,EE,EL,HR,HU,LT,LU,MT,NL,PL,RO,SI,SK Tier 2: 7 MSs AT,BG,FR,IT,LV,PT,SE Tier 3: 4 MSs CZ,FI,IE,UK Not specified or not applicable: 1 MS
Limitations of the Inventory reporting structure	The main limitation is the accuracy of activity data, specifically the area of land to which this action is applied.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

The measure level reports and analyses of the 2007-13 RDPs are too broad brush to permit identification of any support for this climate mitigation action and no summary information is available on the 2014-2020 RDPs. Within the 2014-20 RDPs, one example is Austria, which proposes to use the agri-environment-climate measure (M10.1) to support strip-till seeding[20].

[20] Identified in the LULUCF Article 10 report for Austria.

Where it is appropriate to promote this action the relevant RDP measures could include:

- demonstration activities and information (M 1.2), for example to improve farmers' understanding of how to address potential problems, (for example by the use of mechanical weed control, integrated pest management);
- setting up farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service information on: GHG emissions of the relevant farming practices; on the contribution of the agricultural sector to mitigation through improved farming and agroforestry practices; and on how to improve and optimise soil carbon levels[21];
- agri-environment-climate payments (M10.1) targeted at land where there is a significant risk of soil erosion (provided the requirements of verification and payment control can be met);
- EIP operational groups and pilot projects (M 16.2).

References

McVittie, A (2014) Report on the cost-effectiveness of SOC measures (Deliverable 3.2 of SmartSOIL collaborative project KBBE-2001-5. Sustainable management of agricultural soils in Europe for enhancing food and feed production and contributing to climate change mitigation) http://smartsoil.eu/fileadmin/www.smartsoil.eu/Deliverables/D3_2_Final.pdf

Nix, J. (2013) Farm Management Pocketbook, 44th Edition, Agro Business Consultants Ltd., Leicestershire, UK.

Pronk,A.A, Bijttebier J., Ten Berge, H.,RuysschaertG., Hijbeek R., Rijk, B., Werner M., Raschke I., Steinmann, H.H., Zylowska, K.,Schlatter N., Guzmán G., Syp A., Bechini L., Turpin N., Guiffant N.,Perret, E., Mauhé, N., Toqué, C., Zavattaro L., Costamagna C., Grignani, C., Lehninen, T., Baumgarten, A.,Spiegel, H., Portero, A.,Van Walleghem, T.,Pedrera, A., Laguna, A., Vanderlinden, K.,Giráldez, V., Verhagen A. (2015) Compatibility of Agricultural Management Practices and Types of Farming in the EU to enhance ClimateChange Mitigation and Soil Health List of Drivers and Barriers governing Soil Management by Farmers, including CostAspects Catch-C project Deliverable 4.434 http://www.catch-c.eu/deliverables/D4.434_List_Drivers_Barriers.pdf

Van den Putte, A., Govers, G., Diels, J., Gillijns, K. and Demuzere, M (2010) Assessing the effect of soil tillage on crop growth: A meta-regression analysis on European crop yields under conservation agriculture, *European Journal of Agronomy*, 33, 231–241.

[21] This information is an option for Member States, not a required part of the Farm Advisory Service. Article 12.3 and Annex 1 of Regulation (EU) 1306/2013.

Zero tillage

Description of the MA

Zero tillage is the elimination of all soil tillage. Seed is drilled directly into an uncultivated soil or simply broadcast onto the soil surface. The adoption of zero tillage removes the need for fallow, allowing crops to be grown in every year.

Zero tillage is most suitable to semi-arid areas and is generally less compatible with farming systems in high rainfall areas where yields and crop residues are large. This mitigation action is better suited to self-structuring soils with significant clay content, than to sandy soils.

Mode of action

This mitigation action is considered with respect to its potential for saving energy used for soil cultivation, and sequestering carbon (C) in the soil. Only where crop yields are increased by the introduction of reduced tillage is C sequestration likely to occur.

There may also be changes in emissions of nitrous oxide from soil, but this is not considered further because of a lack of evidence.

Zero tillage has been advocated as a means of sequestering soil carbon. However, more recent reviews and meta-analyses have concluded that, in many cases, zero tillage alters the distribution of C within the soil profile but does not change the total amount of C in soil. A consideration of the mechanisms that lead to SOC accumulation suggests reasons why zero tillage might increase SOC (increased mycorrhizal activity) but also reasons why zero tillage might reduce SOC (incorporating crop residues is more effective at producing stable SOC than leaving residues on the surface).

Increases in SOC occur when:

- The adoption of zero tillage removes the need for fallow, allowing crops to be grown in every year. This increases total dry matter production and can increase soil C as a result of increased crop residue returns.
- Yields of a few crops, e.g. soybeans, can be increased by zero tillage. Again, this increases total dry matter production and can increase soil C as a result of increased crop residue returns.

Mitigation potential

Influencing factors

The mitigation potential of zero tillage depends upon the impacts on crop yields. Only where crop yields (or total production through avoidance of fallow) are increased by the introduction of zero tillage is C sequestration likely to occur. Where zero tillage does sequester C, the practice needs to be maintained as occasional cultivation can release the C sequestered in previous years.

In dry areas, where crop yields can be increased by zero tillage, there can be net C sequestration in soils. However, the exact amounts are difficult to quantify as they will vary according to the crops grown and the soil type.

Table 21: Summary of influencing factors for zero tillage

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Arable (cropland) systems, and any other systems with annual crops (e.g. field vegetables).

Which soil types is this MA relevant to?	Light (i.e. course) soils and soils high in $CaCO_3$.
Which climatic zones is this MA relevant to?	Any, but especially useful in dry regions because there is some conservation of soil water.

Values

For carbon sequestration, a value of 1.13 t CO_2e /ha, +/- 50%, is used, based on information for Spain (representing a semi-arid area) in the SmartSoil report.

Emissions (CO_2) from fuel consumption will be reduced due to the decreased need for cultivation. Estimates of reduced fuel use are taken from the UK MACC for farm energy consumption, and expert knowledge of field operations in arable crops.

We used a range of 5 to 15% of the fuel used in field operations; 76 L of fuel per ha (Nix, 2013), and 3.144 kg CO_2 per L.

The calculated mitigation potential range was 0.0121 to 0.0359 t CO_2e /ha/y.

The mitigation potential at NUTS 2 level, CO_2e/y is shown in Figure 18. Figure 19 and Figure 20 show the mitigation potential looking at carbon sequestration only and energy only.

Figure 18: Mitigation potential at NUTS 2 level, kt CO_2e/y

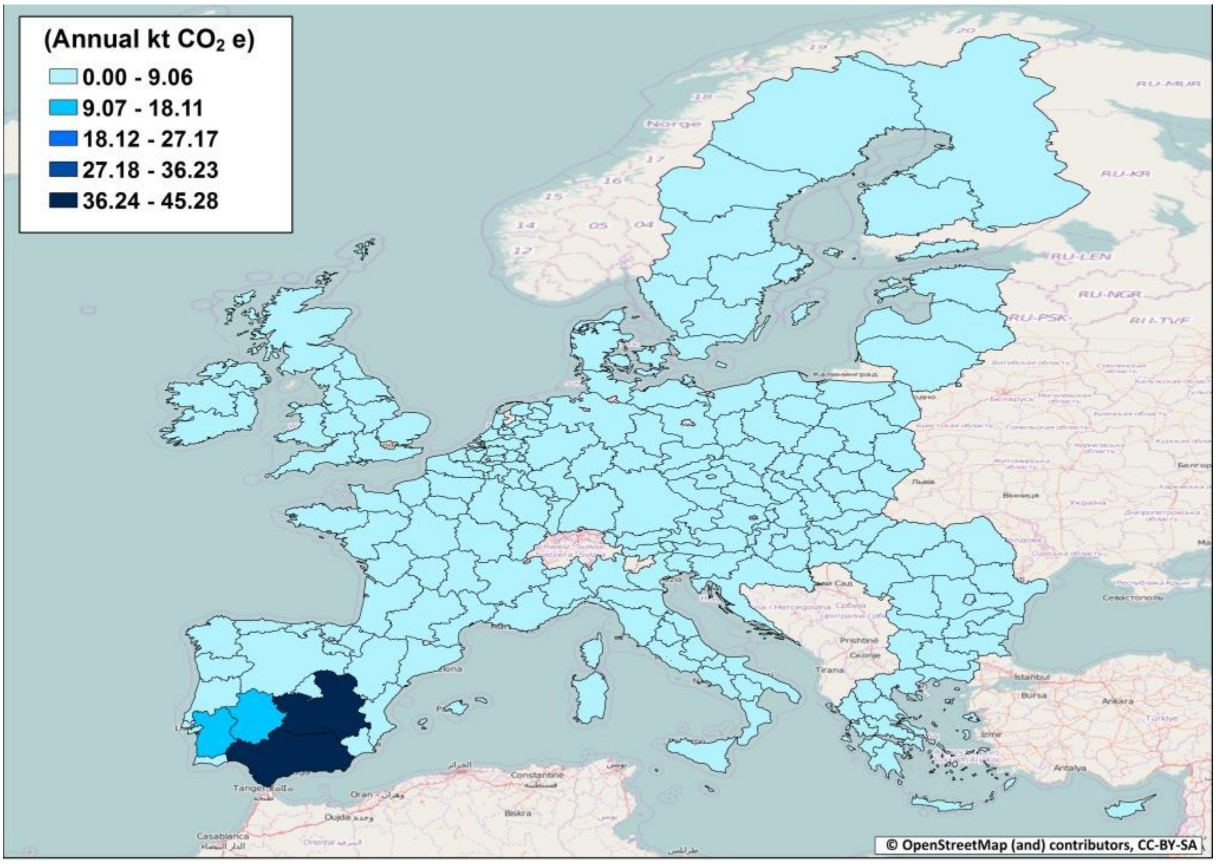


Figure 19: Mitigation potential at NUTS 2 level, kt CO_2e/y (Carbon sequestration only)

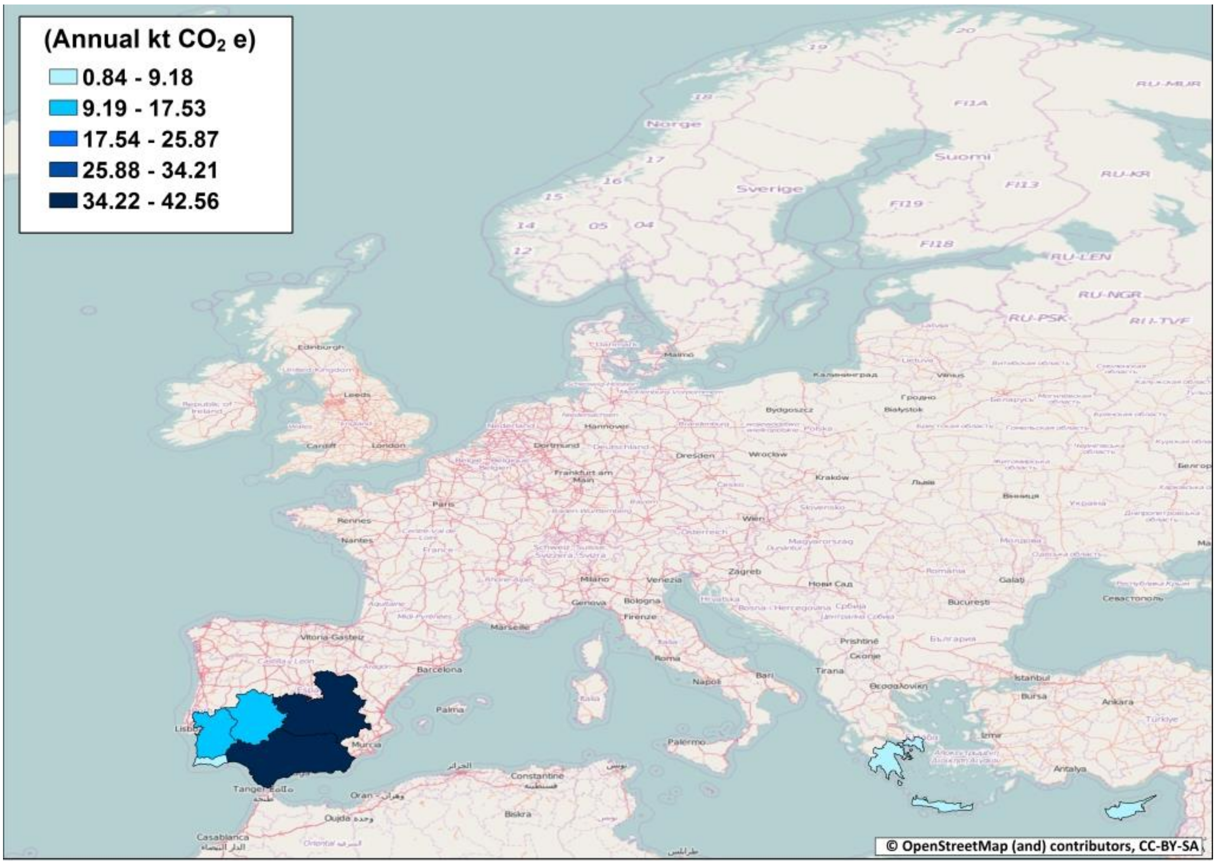
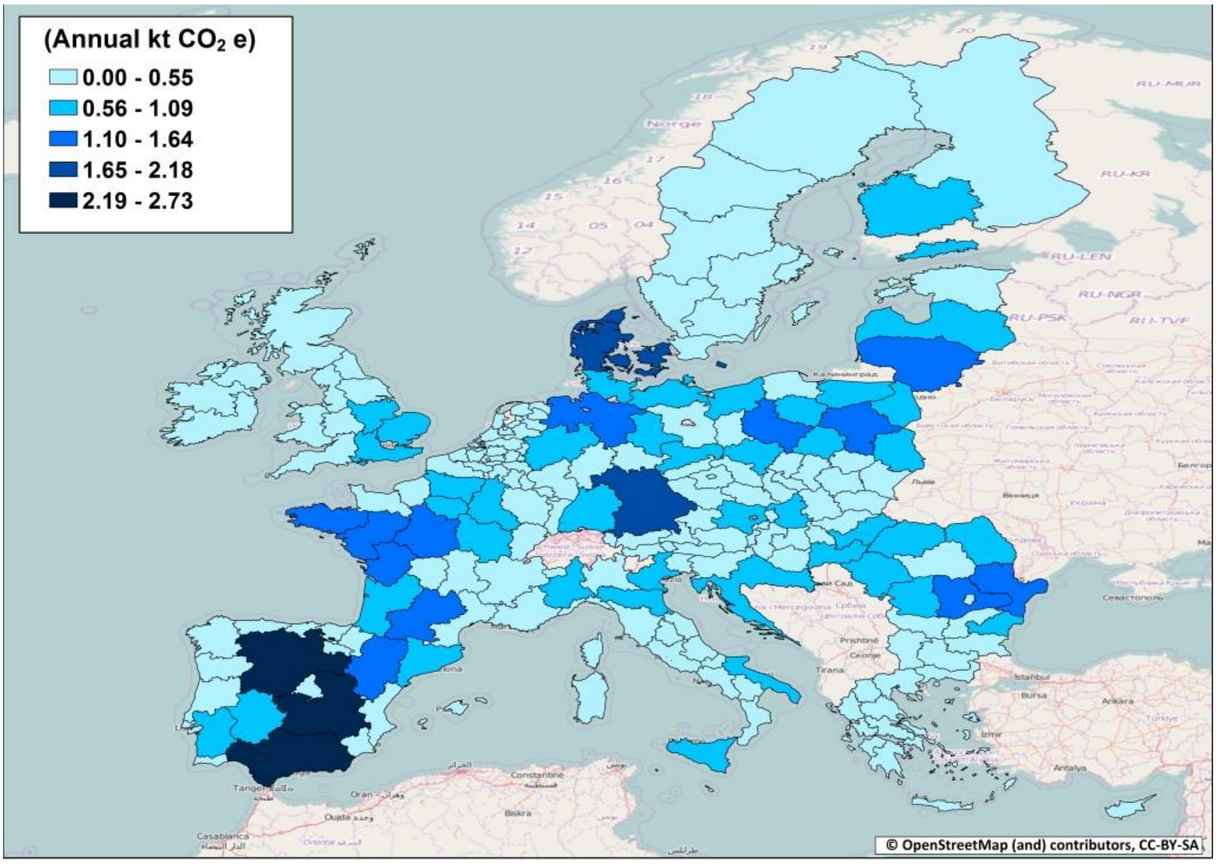


Figure 20: Mitigation potential at NUTS 2 level, kt CO_2e/y (Energy only)



Environmental co-benefits and risks of the MA

There other environmental benefits of this action, additional to the effect on GHG emissions. These benefits could include:

- zero tillage is an effective means of reducing soil erosion, because soil exposure is significantly reduced;
- possible reduction in the dust nuisance caused by field operations; and
- improved soil moisture conservation in semi-arid areas.

There are also risks to the environment from implementing the action and to GHG emissions as a result of the changes to production. These risks could include:

- increased use of herbicides to kill weeds that would otherwise be controlled by ploughing and increased application of slug pellets;
- production displacement if zero tillage is adopted in regions or in cropping systems in which yield is reduced (Van den Putte *et al.,* 2010), leading to increased production elsewhere, possibly in regions where GHG emissions per tonne of crop produced are greater than in the EU;
- in semi-arid areas removing fallow from the rotation may have an adverse impact on biodiversity.

Technological and socio-cultural barriers

Zero tillage systems are well understood and a variety of mechanical cultivation options are available. There are no known socio-cultural barriers to uptake of this climate mitigation action.

Costs/business benefits to land managers of implementing the MA at farm/forest level

Zero tillage is a major change to the farming system and will have an effect on the cropping system of the farm as a whole.

The economic impact on individual farms will be influenced by several factors. Zero tillage requires up-front investment in new field equipment but on-going operational costs will be lower. In most regions crop yields are likely to be similar or less (although some crops, such as soybeans, may show increased yields). There will be savings in field operations (fuel and labour) but crop protection costs may rise if there is a need for increased use of herbicides to kill weeds that would otherwise be controlled by ploughing, increased application of slug pellets, or of fungicides to control plant disease carried from crop residues left on the soil surface. If zero tillage replaces fallow in the rotation it will be possible to grow crops every year.

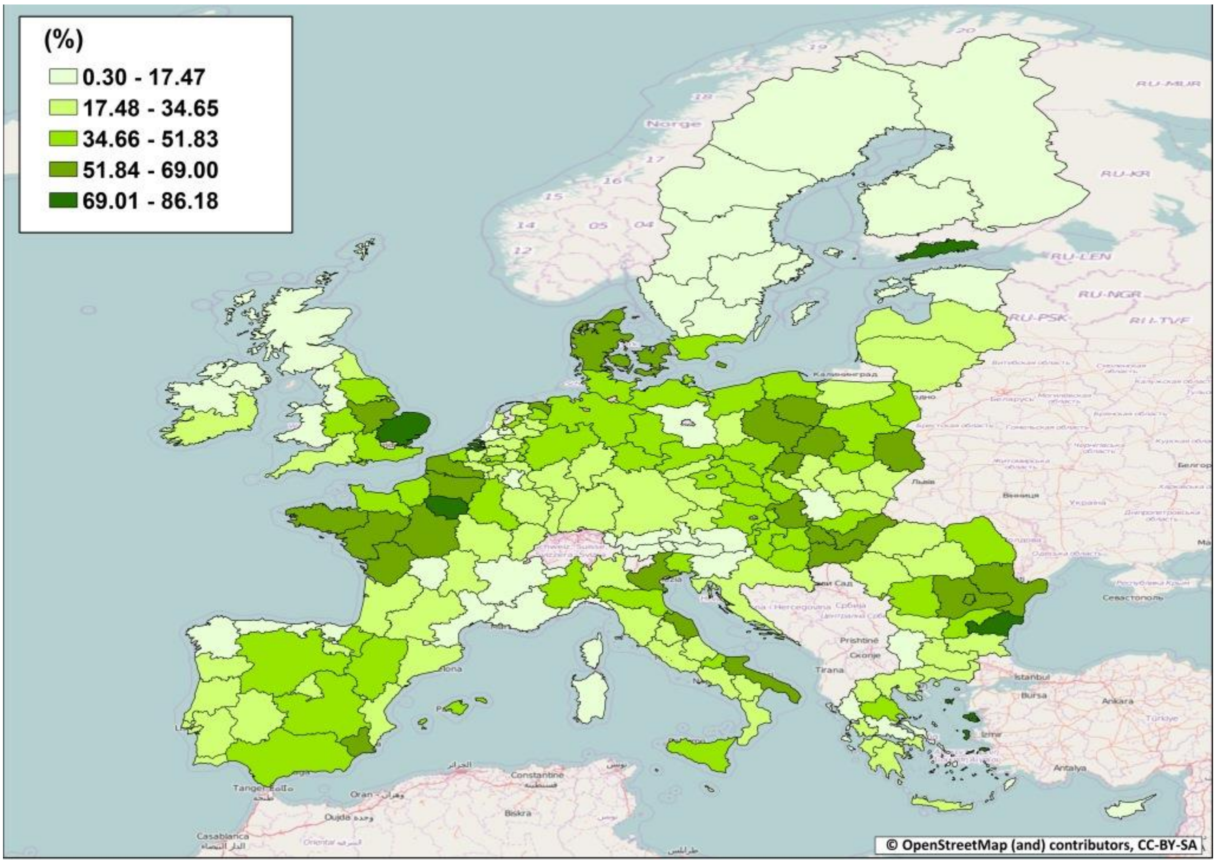
Individual studies from a few Member States provide snapshots of costs but cannot be extrapolated to other regions e.g. one study estimated a saving in input costs for zero tilled cereals in Scotland of £35(€50) per hectare (McVittie, 2014) but potential additional costs associated with increased use of phytosanitary measures (and possibly fertilizers). An earlier study using full costs of introducing zero tillage estimated that, compared to conventional cultivation, non-inversion tillage brought economic benefits of about €60 to €160 per hectare in different parts of Germany (Pronk, 2015, citing Schneider, M., PhD Thesis Munich, 2009).

Farmers could choose to implement this climate mitigation action in the short-term (before 2020), but this decision may be tempered at farm level by the fact that it is a major change to the arable farming system and requires up-front investment.

Geographic relevance

Reduced tillage can take place on arable land. The percentage of land currently in arable production systems, by NUTS 2 areas, is shown in Figure 21.

Figure 21: Land in arable production as a percentage of total area for each NUTS 2 region



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 22.

Table 22: Summary of reporting issues for zero tillage

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes There are several potential mechanisms through which this action may mitigate GHG emissions, including the primary intended mechanism of change in soil organic carbon content. Other changes may be emissions of N_2O and saving in energy for soil cultivations. The latter will result in a reduction in emissions estimated by a national inventory; other mechanisms may or may not influence the national inventories because of availability of activity data.
Is there a methodology that will show specific impact of the	Yes For soil carbon stock change: Refer to 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Vol 4, Ch 5 (cropland), 5.17, section 5.2.3.2, Table 5.5, stock change factors.

mitigation action? What is it?	Tier 1: The effect of the Mitigation Action is detectable, divided into pools: biomass, dead OM, soil carbon. Uses default figures. Tier 2: Relies on some country-specific estimates of the biomass in initial and final land uses rather than the defaults, as in Tier 1. Includes transfer between carbon pools, which changes the emissions total. Tier 3: Increases the accuracy but also has increased costs. Requires countries to have country-specific emission factors, and substantial national data. For CO_2 emissions from energy use: Vol 2, Ch 3, Section 3.3. Tiers 1, 2 and 3 can all be used; the accuracy increases with tier. Agriculture is not necessarily disaggregated from other off-road use of energy.
Categories	Cropland remaining Cropland Direct N_2O emissions from managed soils Indirect N_2O emissions from managed soils Energy, fuel combustion, other sectors
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Cropland remaining Cropland Public Electricity and Heat Production Other Transportation
Which Member States included this as a Key Category in their 2014 National Inventory Reports	Cropland remaining Cropland 23 MSs: AT,BE,BG,CZ,DE,DK,EE,EL,ES,FI,FR,HR,HU,IT,LT,LU,LV,PL,RO,SE, SI,SK,UK Public Electricity and Heat Production 25 MSs: AT,BE,BG,CY,CZ,DE,EE,EL,ES,FI,FR,IE,IT,LT,LU,LV,MT,NL,PL,PT,RO, SE,SI,SK,UK Other Transportation 11 MSs: AT,BG,DE,ES,FI,FR,HU,IE,IT,LT,LU
Tiers used	Cropland remaining Cropland Tier 1: 16 MSs BE,BG,CZ,DE,EE,EL,FI,IE,IT,LU,LV,MT,PL,RO,SI,SK, Tier 2: 4 MSs AT,ES,FR,HU, Tier 3: 2 MSs SE,UK

	Not specified or not applicable: 6 MSs Public Electricity and Heat Production Tier 1: 9 MSs BE,DE,DK,EE,HR,HU,LT,NL,RO Tier 2: 11 MSsAT,BG,CY,EL,FR,LU,LV,PT,SE,SK,UK Tier 3: 5 MSs CZ,FI,IE,IT,SI Not specified or not applicable: 3 MS Other transportation Tier 1: 16 MSsBE,CY,DE,DK,EE,EL,HR,HU,LT,LU,MT,NL,PL,RO,SI,SK Tier 2: 7 MSs AT,BG,FR,IT,LV,PT,SE Tier 3: 4 MSs CZ,FI,IE,UK Not specified or not applicable: 1 MS
Limitations of the Inventory reporting structure	The main limitation is the accuracy of activity data, specifically the area of land to which this action is applied.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

The measure level reports and analyses of the 2007-13 RDPs are too broad brush to permit identification of this climate mitigation action and no summary information is available on the 2015-2020 RDPs. The analysis of the 21015 GAEC standards for 15 Member States showed that eight of them included a standard for minimum soil cover which could be met by zero tillage (although this was not specifically mentioned). It was reported at the project workshop that at least one Mediterranean Member State used the agri-environment measure (M214) to support zero tillage in the 2007-13 RDP.

Where it is appropriate to promote this action the relevant RDP measures could include:

- GAEC 5 minimum land management to limit soil erosion.
- demonstration activities and information (M 1.2), for example to improve farmers' understanding of how to address potential problems, (for example by the use of mechanical weed control, integrated pest management).
- setting up farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service information on: GHG emissions of the relevant farming practices; on the contribution of the agricultural sector to mitigation through improved farming and agroforestry practices; and on how to improve and optimise soil carbon levels[22].
- support for investments in agricultural holdings (M4.1)

[22] This information is an option for Member States, not a required part of the Farm Advisory Service. Article 12.3 and Annex 1 of Regulation (EU) 1306/2013

- agri-environment-climate payments (M10.1) targeted at land where there is a significant risk of soil erosion (provided the requirements of verification and payment control can be met)
- EIP operational groups and pilot projects (M 16.2)

References

McVittie, A (2014) Report on the cost-effectiveness of SOC measures (Deliverable 3.2 of SmartSOIL collaborative project KBBE-2001-5. Sustainable management of agricultural soils in Europe for enhancing food and feed production and contributing to climate change mitigation) http://smartsoil.eu/fileadmin/www.smartsoil.eu/Deliverables/D3_2_Final.pdf

Nix, J. (2013) Farm Management Pocketbook, 44th Edition, Agro Business Consultants Ltd., Leicestershire, UK.

Pronk,A.A, Bijttebier J., Ten Berge, H.,RuysschaertG., Hijbeek R., Rijk, B., Werner M., Raschke I., Steinmann, H.H., Zylowska, K.,Schlatter N., Guzmán G., Syp A., Bechini L., Turpin N., Guiffant N.,Perret, E., Mauhé, N., Toqué, C., Zavattaro L., Costamagna C., Grignani, C., Lehninen, T., Baumgarten, A.,Spiegel, H., Portero, A.,Van Walleghem, T.,Pedrera, A., Laguna, A., Vanderlinden, K.,Giráldez, V., Verhagen A. (2015) Compatibility of Agricultural Management Practices and Types of Farming in the EU to enhance ClimateChange Mitigation and Soil Health List of Drivers and Barriers governing Soil Management by Farmers, including CostAspects Catch-C project Deliverable 4.434 http://www.catch-c.eu/deliverables/D4.434_List_Drivers_Barriers.pdf

Van den Putte, A., Govers, G., Diels, J., Gillijns, K. and Demuzere, M (2010) Assessing the effect of soil tillage on crop growth: A meta-regression analysis on European crop yields under conservation agriculture, *European Journal of Agronomy*, 33, 231–241.

Leaving crop residues on the soil surface

Description

Crop residues are left on the soil surface after harvest. The greater the crop yield, the more residues will be available and the greater the C sequestration potential will be.

Mode of action

This mitigation action is considered with respect to its potential for sequestering C in the soil. Leaving crop residues in the field will enable greater C retention in soils than removing crop residues. However, two factors need to be considered.

First, if crop residues are used for livestock bedding they will ultimately be returned to the soil and lead to increased soil C.

Second, incorporation of crop residues into soil is a more effective means of increasing soil C than leaving residues on the surface. Incorporation of residues may also be more effective in utilising organic matter to improve soil structure.

While retaining crop residues may also reduce the demand for N fertilizer and the associated emissions of N_2O, there will also be additional N_2O emissions from retaining crop residues. The balance between these in very uncertain and therefore the impacts on N_2O emissions have not been estimated. However, reporting of N_2O emissions is considered in the section below on reporting the mitigation effect.

Mitigation potential

Influencing factors

The greater the crop yield, the more residues will be available and the greater the C sequestration potential will be. In dry areas, where crop yields can be increased as a result of crop residues acting as a mulch and conserving moisture, there can be additional net C sequestration in soils. However, the exact amounts are difficult to quantify as they will vary according to the crops grown and the soil type.

Crop residues mixed with soil appear to lead to more longer-lasting increases in SOC than crop residues left on the surface (Angers and Eriksen-Hamel, 2008). Balesdent *et al.,* (2000) suggested that the contact of organic matter with the clay matrix following incorporation of crop residues by mouldboard ploughing may reduce biodegradation. Furthermore, the efficiency of C stabilization of fresh residues increased when incorporated in the top 30 cm compared with a shallower depth (15 cm) (Olchin *et al.,* 2008). Accumulation of transformed SOC in tilled soils is supported by field observations where conventional tillage was compared with zero tillage systems. Microbial biomass C was found to be greater under conventional tillage than zero tillage at the 15 to 30 cm depth in several soils (Doran, 1987; Doran *et al.,* 1998). Humic acid and the humification index (Horáček *et al.,* 2001), as well as the incorporation of crop residues in humic fractions (Murage and Voroney, 2008), were significantly greater under conventional tillage than zero tillage below 5 cm. Furthermore, adsorption of organic molecules to the fine mineral particles may be more effective in deeper horizons because mineral surfaces are probably less saturated than at the surface (Rasse *et al.,* 2006).

The complexity of the influencing factors leads to a wide range of mitigation potential values. In summary, this is justified by the considerable variation in potential C sequestration as a result of the following factors:

- The C sequestration potential of soils will depend upon the initial soil C content and how much that value is below the potential soil C capacity.
- The C sequestration potential of soils will depend upon the soil clay content with greater potential for clay soils.

- The greater the amounts of crop residues that can be retained the greater will be the potential sequestration. The amounts available will depend upon soil type and climate being greatest on soils with the greatest available water-holding capacity and in regions with adequate rainfall during the growing season and/or irrigation.
- The nature of the crop residues, in particular the C:N ratio, with smaller C:N ratios favouring C sequestration.

Table 23: Summary of influencing factors for leaving crop residues on the soil surface

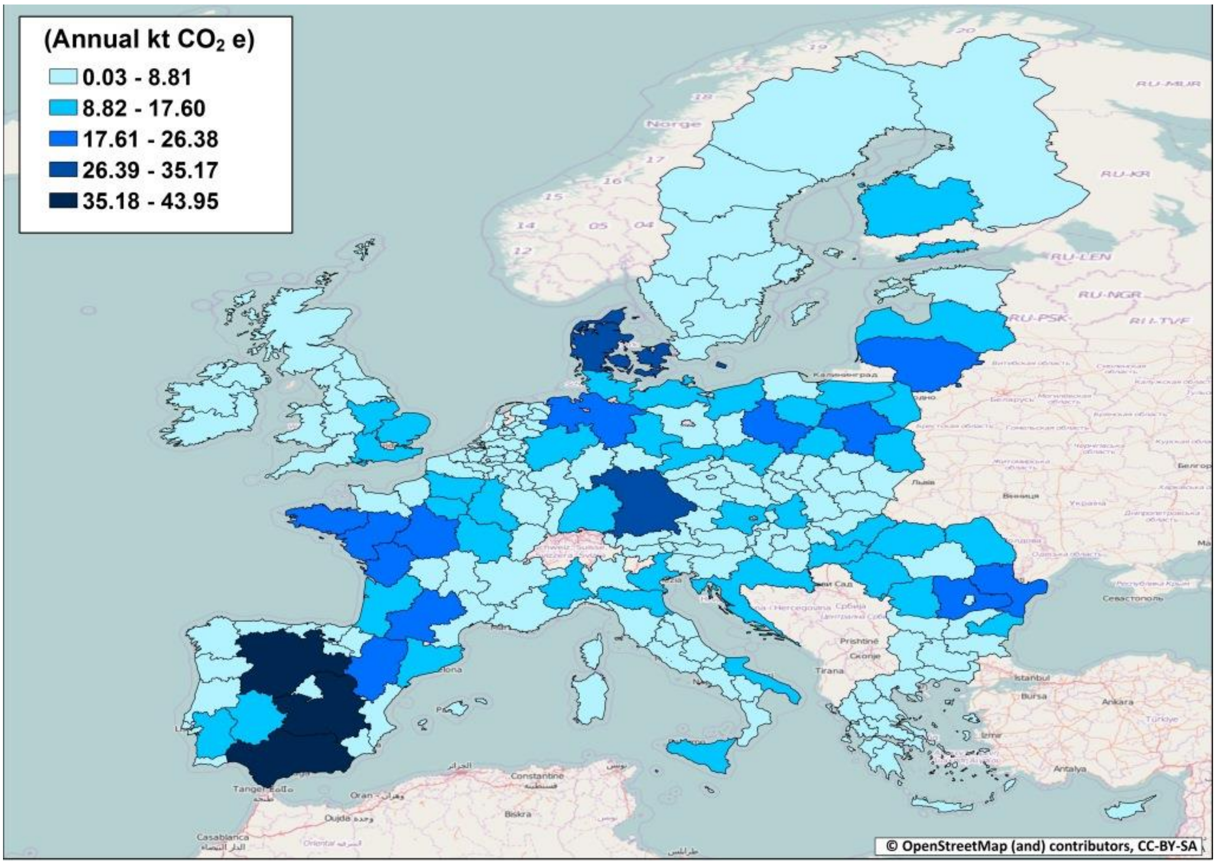
Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Many arable crops in arable (cropland) systems.
Which soil types is this MA relevant to?	Any.
Which climatic zones is this MA relevant to?	Any.

Values

We used a range of 0.11 to 2.2 t/ha/y CO_2e, based on values reported by Frelih-Larsen *et al.,* (2014), and Posthumus *et al.,* (2013).

The mitigation potential at NUTS 2 level, CO_2e/y is shown in Figure 22.

Figure 22: Mitigation potential at NUTS 2 level, kt CO_2e/y



Environmental co-benefits and risks of the MA

There other environmental benefits of this action, additional to the effect on GHG emissions. These benefits could include:

- leaving crop residues on the soil surface can help to reduce soil erosion;
- the residues can improve soil moisture conservation in semi-arid areas; and
- incorporating crop residues can improve soil fertility and benefit soil biodiversity.

There are also risks to the environment from implementing the action and to GHG emissions as a result of the changes to production. These risks could include:

- increased use of fungicides and slug pellets;
- production displacement if zero tillage is adopted in regions or in cropping systems in which yield is reduced (Van den Putte *et al.,* 2010), leading to increased production elsewhere, possibly in regions where GHG emissions per tonne of crop produced are greater than in the EU.

Technological and socio-cultural barriers

There are no technological or socio-cultural barriers associated with leaving crop residues on the soil surface, and the practice is straightforward to implement.

Costs/business benefits to land managers of implementing the MA at farm/forest level

Leaving crop residues on the soil surface can save costs by reducing labour and fuel inputs and by reducing wear on machinery, but crop protection costs may rise if there is a need for increased application of slug pellets, or of fungicides to control plant diseases carried from crop residues left on the soil surface. Returning crop residues to the soil is likely to bring benefits to soil quality.

The net impact on farm income is variable, but depends principally on whether or not there is an alternative economic use for the residues, for example using straw as fodder or bedding for livestock or if there is a local market for straw or pruning from permanent crops as biomass for renewable energy production. If the crop residues have no economic end use the savings in costs, mainly labour, from leaving them in the field can exceed the reductions in income from lower yield, with the balance between the two most likely to be favourable where labour costs are greatest and where there is potential for increased crop yields.

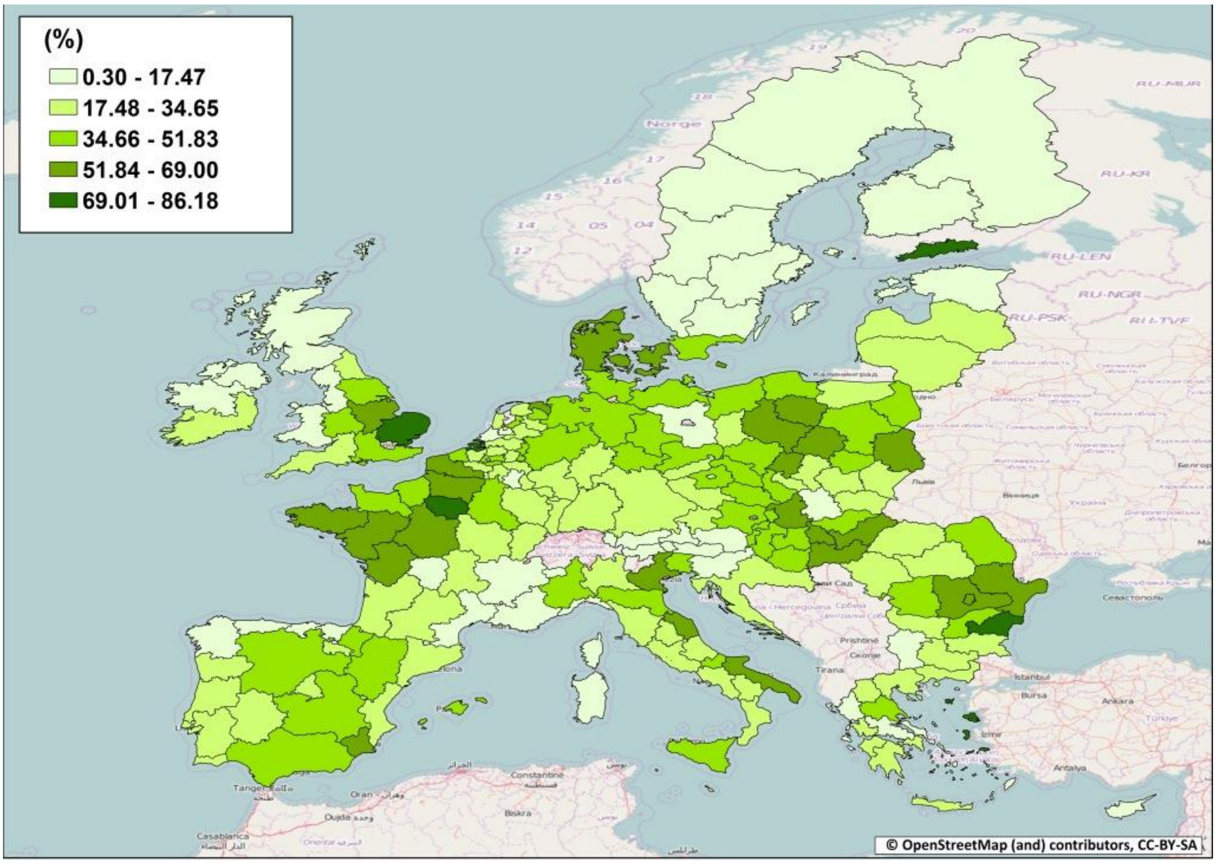
A recent analysis for regions in six Member States indicated an average loss of income from selling straw or additional costs incurred for animal feed if straw was no longer used fodder to vary widely, at €53.7/ha in Denmark, €47.5/ha in Hungary, €20.4/ha in Italy, €154.3/ha in Poland, €58.8/ha in Spain and105.8/ha in the UK (SMartSOIL, 2015).

Farmers could choose to implement this climate mitigation action in the short-term (before 2020), but individual decisions will be influenced by the economic impact on the farm business and possibly other factors.

Geographic relevance

Reduced tillage can take place on arable land. The percentage of land currently in arable production systems by NUTS 2 area is shown in Figure 23.

Figure 23: Land in arable production as a percentage of total area for each NUTS 2 region



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 24.

Table 24: Summary of reporting issues for leaving crop residues on the soil surface

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes The mechanisms through which this action may mitigate GHG emissions include change in soil organic carbon content and change in emissions of N_2O from soil. However, these mechanisms may or may not influence the national inventories because of availability of activity data.
Is there a methodolog y that will show specific impact of the	Yes For direct N_2O emissions: Vol 4, Ch 11, Section 11.2. Tiers 1, 2 and 3 can all be used; the accuracy increases with tier. Tier 1: gives a simple linear relationship between the amount of N_2O emissions and the amount of nitrogen applied. More specific emission factors are used in tiers 2 and 3, improving accuracy.

mitigation action? What is it?	For indirect N_2O emissions: Vol 4, Ch 11, Section 11.2. Tiers 1, 2 and 3 can all be used; the accuracy increases with tier. Tier 1: gives a simple linear relationship between the amount of N_2O emissions and the amount of nitrogen applied. More specific emission factors are used in tiers 2 and 3, improving accuracy. For soil carbon stock change: Refer to 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Vol 4, Ch 5 (cropland), 5.17, section 5.2.3.2, Table 5.5, stock change factors. Tier 1: The effect of the Mitigation Action is detectable, divided into pools: biomass, dead OM, soil carbon. Uses default figures. Tier 2: Relies on some country-specific estimates of the biomass in initial and final land uses rather than the defaults, as in Tier 1. Includes transfer between carbon pools, which changes the emissions total. Tier 3: Increases the accuracy but also has increased costs. Requires countries to have country-specific emission factors, and substantial national data.
Categories	Direct N_2O emissions from managed soils Indirect N_2O emissions from managed soils Cropland remaining Cropland
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Agricultural soils Cropland remaining Cropland
Which Member States included this as a Key Category in their 2014 National Inventory Reports	Agricultural soils, direct 27 MSs: AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,FR,HR,HU,IE,IT,LT,LU,LV,MT,NL,PL, PT,RO,SE,SI,SK,UK Agricultural soils, indirect 27 MSs: AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,FR,HR,HU,IE,IT,LT,LU,LV,MT,NL,PL, PT,RO,SE,SI,SK,UK Cropland remaining Cropland 21 MSs: AT,BG,CZ,DE,DK,EE,EL,ES,FI,FR,HR,IT,LT,LU,LV,PL,RO,SE,SI,SK,UK
Tiers used	Agricultural soils, direct Tier 1: 23 MSs AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,HR,IT,LT,LU,LV,MT,PL,PT,RO,SE,SI,SK, UK Tier 2: 4 MSs FR,HU,IE,NL

	Tier 3: 0 MSs Not specified or not applicable: 1 MS Agricultural soils, indirect Tier 1: 23 MSs AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,HR,IT,LT,LU,LV,MT,PL,PT,RO,SE,SI,SK, UK ,,,,,Tier 2: 4 MSs ES,FR,HU,IE Tier 3: 0 MSs Not specified or not applicable: 1 MS Cropland remaining Cropland Tier 1: 18 MSs BE,BG,CZ,DE,DK,EE,EL,FI,IE,IT,LT,LU,LV,MT,PL,RO,SI,SK Tier 2: 4 MSs AT,FR,HR,HU Tier 3: 2 MSs SE,UK Not specified or not applicable: 4 MSs
Limitations of the Inventory reporting structure	The main limitation is the accuracy of activity data, specifically the area of land to which this action is applied.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

The GAEC standards for arable stubble management are relevant to this climate mitigation action if these apply to the crop residues as well as to the stubble itself (but this not always clear). In the 2014 GAEC standards burning stubble on arable land was prohibited in all Member States (although it does not appear to be specified as a GAEC requirement in FR, HU and IE; this may be because it is already a requirement in national legislation). Several Member States put additional requirements in place related to ploughing-in stubbles, including Bulgaria and Cyprus (where appropriate) and in special circumstances in Greece, Italy, Malta and the UK. Exceptions to the arable stubble management requirements were allowed, and these related to plant health in Austria, Croatia, Cyprus, Denmark, Finland, Lithunia, Malta and Spain) to weather in Austria; straw is used for soil cover in DK and LU (during March to September) or is waste in Lithuania. Other Member States did not define the exceptions but simply required farmers to seek special permission, in Greece, in southern regions of Italy (where stubble burning is part of traditional land management); in Portugal and the Netherlands.

Of the 2015 GAEC standards examined for this study, eight referred to a ban on burning straw or residues in the summary text (but for the others it is possible that the detailed national legislation on which the standard is based does make reference to residues).

The measure level reports and analyses of the 2007-13 RDPs are too broad brush to permit identification of any support for this climate mitigation action and no summary information is available on the 2015-2020 RDPs.

Some LIFE projects focused on soil management have not only demonstrated improvements in agricultural practices but have also taken steps to measure the amount of carbon that is sequestered in the soil along with the organic matter increase. For example the oLIVE-CLIMA project (LIFE11 ENV/GR/000942) demonstrated ways of improving farming techniques in olive production such as pruning, crop cover, returning organic matter to the soil (European Commission, 2014).

Where it is appropriate to promote this action the most relevant CAP measures could include:

- GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)

Incentive payments for leaving residues in the field are unlikely to be appropriate because individual farmers will choose the most economically effective way of dealing with crop residues, which will vary from farm to farm and year to year.

References

Angers D.A and Eriksen-Hamel N.S (2008) Full-Inversion Tillage and Organic Carbon Distribution in Soil Profiles: A Meta-Analysis, *Soil Science Society of America Journal,* 72, 1370-1374.

Balesdent, J., C. Chenu, and M. Balabane (2000) Relationship of soil organic matter dynamics to physical protection and tillage, *Soil and Tillage Research*, 53, 215–230.

Doran, J.W (1987) Microbial biomass and mineralizable nitrogen distributions in no-tillage and plowed soils, *Biology and Fertility of Soils,* 5, 68–75.

Doran, J.W., E.T. Elliott, and K. Paustian (1998) Soil microbial activity, nitrogen cycling, and long-term changes in organic carbon pools as related to fallow tillage management, *Soil & Tillage Research,* 49, 3–18.

European Commission (2014) LIFE and Soil protection. LIFE Environment. http://ec.europa.eu/environment/life/publications/lifepublications/lifefocus/documents/soil_protection.pdf

Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu, J.L., Lasorella, M.V. and Longhitano, D (2014) "Mainstreaming climate change into rural development policy post 2013." Final report. Ecologic Institute, Berlin.

Horáček, J., R. Ledvina, and A. Raus (2001) The content and quality of organic matter in Cambisol in a long-term no-tillage system, *Rostlinna Vyroba*, 47, 205–210.

Murage, E.W., and R.P. Voroney (2008) Distribution of organic carbon in the stable humic fractions as affected by tillage management, *Canadian Journal of Soil Science*, 88, 99–106.

Olchin, G.P., S. Ogle, S.D. Frey, T.R. Filley, K. Paustian, and J. Six (2008) Residue carbon stabilization in soil aggregates of no-till and tillage management of dryland cropping systems, *Soil Science Society of America Journal*, 72, 507–513.

Posthumus, H., Deeks, L.K., Rickson, R.J and Quinton, J.N (2013) Costs and benefits of erosion control measures in the UK. Soil Use and Management, DOI: 10.1111/sum.12057

Pronk,A.A, Bijttebier J., Ten Berge, H.,RuysschaertG., Hijbeek R., Rijk, B., Werner M., Raschke I., Steinmann, H.H., Zylowska, K.,Schlatter N., Guzmán G., Syp A., Bechini L., Turpin N., Guiffant N.,Perret, E., Mauhé, N., Toqué, C., Zavattaro L., Costamagna C., Grignani, C., Lehninen, T., Baumgarten, A.,Spiegel, H., Portero, A.,Van Walleghem, T.,Pedrera, A., Laguna, A., Vanderlinden, K.,Giráldez, V., Verhagen A. (2015) Compatibility of Agricultural Management Practices and Types of Farming in the EU to enhance ClimateChange Mitigation and Soil Health List of Drivers and Barriers governing Soil Management by Farmers, including

CostAspects Catch-C project Deliverable 4.434 http://www.catch-c.eu/deliverables/D4.434_List_Drivers_Barriers.pdf

SmartSOIL (2015) SmartSOIL Factsheet Residue Management: Improving soil organic matter and reducing soil erosion http://smartsoil.eu/fileadmin/www.smartsoil.eu/WP5/Factsheets/SmartSOIL_facksheet_residue-management_final2.pdf

Rasse, D.P., Mulder, J., Moni, C. and Chenu, C (2006) Carbon turnover kinetics with depth in a French loamy soil, *Soil Science Society of America Journal,* 70, 2097–2105.

Ceasing to burn crop residues and vegetation

Description

This mitigation action involves ceasing to burn vegetation and crop residues. Legislation within the EU has largely outlawed the practice of field burning agricultural wastes, but there are minor exceptions. Burning of vegetation and crop residues was banned in England in 1992, as cited in Feliciano *et al.,* (2013). Burning is still carried out in other parts of the world to clear the field of organic debris, enhance soil fertility and control unwanted diseases, weeds and pests (Erenstein, 2003). Estrellan and Lion (2010) explain burning of agricultural residues as 'an inexpensive means to advance crop rotation and control insects, disease, and the emergence of invasive weed species'.

Mode of action

Burning crop residues produces carbon monoxide (CO), methane (CH_4), N_2O and other oxides of nitrogen (NOx) (Eurostat, 1999). The ceasing of burning crop residues would therefore lower the emissions of these gasses.

Removing crop residues results in a reduction of SOC (Smith *et al.,* 2012). As stated by Reijnders, (2008), 'full return of crop residues to arable soils may increase soil SOC levels by up to 0.7 Mg C ha^{-1} $year^{-1}$'.

Mitigation potential

Influencing factors

The main influencing factor is the current level of GHG emissions that can be prevented by ceasing the activity.

Table 25: Summary of influencing factors for ceasing to burn crop residues and vegetation

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	All crop types, including annual and perennial crops, and forage crops in livestock systems.
Which soil types is this MA relevant to?	Any.
Which climatic zones is this MA relevant to?	Any.

Values

'Burning of residues contributed to 0.3% of CH_4 emissions at the European Level in 1996' (Eurostat, 1999). A small mitigation potential is therefore possible if residues are not burnt.

0.1% of N_2O sources in the United States are from field burning (Johnson *et al.,* 2007).

It was also noted by Toma *et al.,* (2010; cited in Dufosse *et al.,* 2014) that soil carbon in the topsoil layer did not change before and after the burning of crop residues. It was also stated that '57% of C accumulation from biomass remains after burning, as ashes and charcoal'.

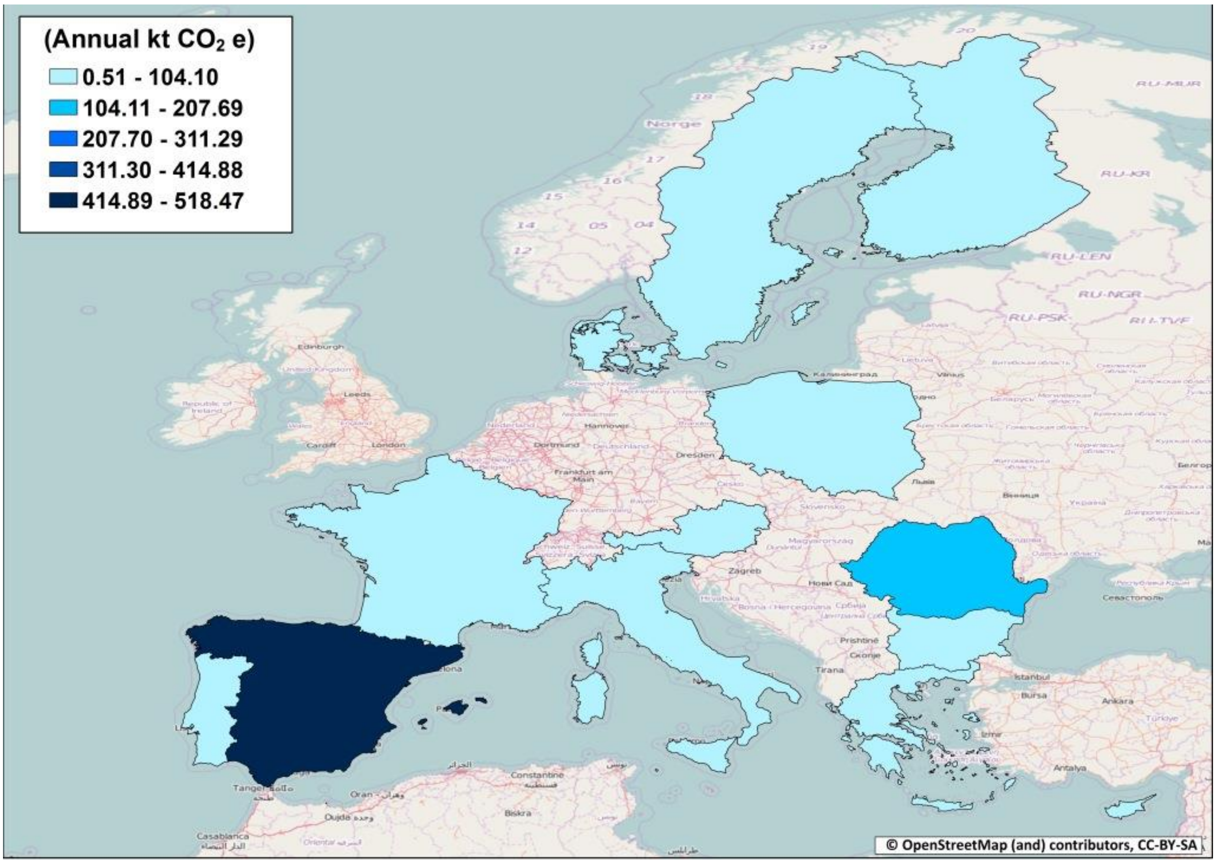
While burning crop residues produces very small emissions of CH_4 and N_2O the major gain from allowing crop residues to remain unburnt will be to add carbon to the soil. The values below were derived from studies evaluated in this report.

Reijnders, (2008), reported that the return of crop residues to arable soils may increase soil SOC levels by up to 0.7 t C ha^{-1} $year^{-1}$. We took a conservative estimate of 0.6 t ha^{-1} $year^{-1}$ as the upper end of the range and 0.2 t C ha^{-1} $year^{-1}$ as the lower end.

We used a simple approach of recording the GHG emissions from this source, as given in national inventory reports for 2012 (2014 submission), by Member State, as the mitigation potential. Values were zero for many Member States, and the maximum value was 0.512 Mt CO_2e per year for Spain.

The mitigation potential at Member State level (kt CO_2e/y) is shown in Figure 24.

Figure 24: Mitigation potential at Member State level, kt CO_2e/y



Environmental co-benefits and risks of the MA

There are other environmental benefits of this action, additional to the direct effect on GHG emissions. These benefits could include:

- less smoke, soot and particulate matter released into the air, with positive benefits for public health and road safety;
- availability of crop residues as biomass for energy production;
- reduced risk of fire damage to trees, woodland, forests, heathland, buildings and infrastructure.

There are also risks to the environment from implementing the action, which may include:

- increased use of herbicides and pesticides to control crop pests, diseases and invasive weed species which would be controlled by burning.

Technological and socio-cultural barriers

There has been a preference in some farming systems to burn residues rather than incorporate them into the soil, mainly to reduce cultivations and improve seedbed quality. However, in

Member States where the residue burning has been banned farmers have been able to adapt to new practices. In many countries controlled burning of semi-natural pastureland has long been used as a management tool to remove dead or overgrown vegetation and encourage new, more palatable growth.

Costs/business benefits to land managers of implementing the MA at farm/forest level

Ceasing burning crop residues is unlikely to have an impact on farm income, and some farms may already have found an economic end use for the residues, for example as fodder or bedding for livestock or as biomass for renewable energy production. Where this is not the case a ban on burning residues could possibly stimulate a market for alternative uses within the rural economy.

Those farmers not already implementing this climate mitigation action could do so in the short-term (before 2020), but individual decisions will be influenced by the economic impact on the farm business and possibly other factors, for example traditional use of burning as a management technique on rough grazing.

Geographic relevance

Ceasing to burn crop residues and vegetation can take place on any arable land where burning is practiced. The map of mitigation potential at Member State level (kt CO_2e/y; Figure 24) therefore illustrates the geographic relevance.

Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 26.

Table 26: Summary of reporting issues for ceasing to burn crop residues and vegetation

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes Field burning of agricultural residues does not occur in many MSs. Where it does occur it leads to emissions of CO_2 and other non-CO_2 GHGs. Only the non-CO_2 GHGs are reported because it is assumed that the CO_2 emissions would be counterbalanced by CO_2 removals from the subsequent re-growth of the vegetation within one year.
Is there a methodology that will show specific impact of the mitigation action? What is it?	Yes Refer to 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Vol 4, Ch 5, section 5.2.4 Non- CO_2 greenhouse gas emissions from biomass burning; this refers to Vol 4, Ch 2, Section 2.4. Tier 1: activity data highly aggregated, default emissions factors. GHG emissions as a result of the MA would be detected. Tier 2: increased accuracy, estimates for the major crop types by climate zone, using country-specific residue accumulation rates and country-specific combustion and emission estimates. Tier 3: very country-specific, involving process modelling and/or detailed measurement. Accuracy will increase with increasing tiers but all of the tiers would detect this measure.

Categories	Field burning of agricultural residues
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Field burning of agricultural residues
Which Member States included this as a Key Category in their 2014 National Inventory Reports	2 MSs: FR,PL
Tiers used	Tier 1: 10 MSsAT,BG,CY,DK,EE,FI,HU,IT,RO,UK Tier 2: 0 MSs Tier 3: 0 MSs Not specified or not applicable: 18 MSs
Limitations of the Inventory reporting structure	The Tier 1 method deals with only four specific crop types – so if the crop is not one of these the closest approximation would have to be used. Activity data on the area burnt is needed.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

The GAEC standards for arable stubble management are relevant to this climate mitigation action where they apply to the crop residues as well as to the stubble itself (although this distinction is not always clear in the summary documents reviewed for this study). In the 2014 GAEC standards burning stubble on arable land was prohibited in all Member States (with exceptions where burning is necessary for phyto-sanitary reasons) although it does not appear as a specific GAEC requirement in FR, HU and IE, perhaps because it is already a requirement in national legislation. Several Member States put additional requirements in place related to ploughing-in stubbles, including Bulgaria and Cyprus (where appropriate) and in special circumstances in Greece, Italy, Malta and the UK. Exceptions to the arable stubble management requirements were allowed, and these related to plant health in Austria, Croatia, Cyprus, Denmark, Finland, Lithuania, Malta and Spain) to weather in Austria; straw is used for soil cover in DK and LU (during March to September) or is waste in Lithuania. Other Member States did not define the exceptions but simply required farmers to seek special permission for burning, in Greece, in southern regions of Italy (where stubble burning is part of traditional land management), in Portugal and the Netherlands[23].

From 2015, under the new EU framework for cross-compliance, all Member States must include a ban on burning arable stubble, except for plant health reasons in their GAEC 6 definition. Of the fifteen GAEC standards for 2015 reviewed for this study, eight referred to a ban on burning straw or residues in the summary text (in the other cases the detailed national legislation on which the standard is based does make reference to residues). Seven of the 15 standards banned the burning of grassland and/or other vegetation (e.g. heathland, reeds) or defined specific requirements for burning vegetation.

[23] Data is for 2014 standards except for UK (Wales) which is 2013) Source: Mars Wiki JRC (2014) downloaded on 4 December 2014 https://marswiki.jrc.ec.europa.eu/gaec/appl.php

Where burning residues or vegetation is not already specifically prohibited by GAEC standards or national legislation the relevant CAP measure to promote it is:

- GAEC 6 maintenance of soil organic matter
- demonstration activities and information (M 1.2)
- setting up farm and forestry advisory services (M 2.2) to provide through the Member State's Farm Advisory Service information on: GHG emissions of the relevant farming practices; on the contribution of the agricultural sector to mitigation through improved farming and agroforestry practices; and on how to improve and optimise soil carbon levels[24].

References

Dufosse, K., Drewer, J., Gabrille, B. and Drouet, J.L. (2014) Effects of a 20-year old *Miscanthus x giganteus* stand and its removal on soil characteristics and greenhouse gas emissions, *Biomass and Bioenergy*, 69, 198-210.

Erenstein, O. (2003) Smallholder conversation farming in the tropics and sub-tropics: a guide to the development and dissemination of mulching with crop residues and cover crops, *Agriculture, Ecosystems and Environment*, 100, 17-37.

Estrellan, C.R. and Lino, F. (2010) Toxic emissions from open burning, *Chemosphere*, 80, 193-207.

Eurostat (1999) Agriculture, Environment, Rural Development: Facts and Figures – A Challenge for Agriculture, http://ec.europa.eu/agriculture/publi/reports/envir1999_en.pdf, accessed 6th October 2014

Feliciano, D., Hunter, C., Slee, B. and Smith, P. (2013) Selecting land-based mitigation practices to reduce GHG emissions from the rural land use sector: A case study of North East Scotland, *Journal of Environmental Management*, 120, 93-104.

Johnson, J.M.F., Franzluebbers, A.J., Weyersm S.L. and Reicosky, D.C. (2007) Agricultural opportunities to mitigate greenhouse gas emissions, *Environmental Pollution*, 150, 107-124.

Reijnders, L. (2008) Ethanol production from crop residues and soil organic carbon, *Resources, Conservation and Recycling*, 52, 653-658.

Smith, W.N., Grant, B.B., Campbell, C.A., McConkey, B.G., Desjardins, R.L., Krobel, R. and Malhi. S.S. (2012) Crop residue removal effects on soil carbon: Measured and inter-model comparisons, *Agriculture, Ecosystems and Environment*, 161, 27-38.

[24] This information is an option for Member States, not a required part of the Farm Advisory Service. Article 12.3 and Annex 1 of Regulation (EU) 1306/2013

Use cover/catch crops

Description

Decreasing the area and/or duration of bare fallow has been used as an action to reduce GHG emissions and SOC loss (Abdalla *et al.,* 2014). Cover crops are used to reduce the period of time that soil is left bare in order to reduce the risk of soil erosion. Catch crops are grown to reduce the duration of bare soil between harvest and the following spring in order to take up mobile nutrients, such as nitrate, and hence reduce pollution of watercourses. The same crops may often be used for the two purposes or both together. Such crops can be 'annual, biennial, or perennial herbaceous plants grown in a pure or mixed stand during all or part of the year (Abdalla *et al.,* 2014). A cover crop can be undersown in the previous crop, sown before harvest, or sown post-harvest (Thorup-Kristensen *et al.,* 2003; cited in Petersen *et al.,* 2011).

This mitigation action is considered with respect to its potential for sequestering C in soil and reducing emissions of N_2O.

Mode of action

Depending on the type of crop used, a number of benefits can be seen. Legume cover crops can suppress weeds, increase SOC, and reduce the amount of N fertilizer required for subsequent crops, as they are able to biologically fix N (Abdalla *et al.,* 2014). Non-legume cover crops also bring benefits by taking up excess soil nutrients, and improving the structure of the soil (Abdalla *et al.,* 2014).

Sowing a catch/cover crop in the autumn before cultivation of a spring crop to reduce the fallow period reduces losses of N_2O and soil nitrate (Sundermeier, 2009; cited in Abdalla *et al.,* 2014).

Soil organic carbon inputs are also increased by cover crops due to the increased duration of vegetation cover (Campbell *et al.,* 2001; cited in Abdalla *et al.,* 2014).

The main emissions categories and climate change risks that cover crops/reducing bare fallow protect against are CO_2 emissions from soil carbon loss, soil erosion and the consequences of this (e.g. productivity changes in the long-term) (Frelih-Larsen *et al.,* 2014).

'Cover crops can mitigate GHG emissions in the following ways:

- Increase of soil organic carbon content (sequestration).
- Decrease soil erosion during the fallow period.
- Reduction in N leaching and in the amount of N that needs to be applied to the following crop, leading to lower N_2O emissions.

Mitigation potential

Influencing factors

As stated by Parkin *et al.,* (2006; cited in Abdalla *et al.,* 2014), 'Rye cover crops accumulate significant proportions of applied N, greatly reducing the amount of NO_3 lost in drainage water, reduce soil inorganic N levels, increase evapotranspiration, and reduce drainage losses and N_2O emissions'.

A contrasting view, however, is that crop residues with low C:N ratios, e.g. legume crops, may increase N_2O emissions (Toma and Hatano, 2007; cited in Abdalla *et al.,* 2014). Gomes *et al.,* (2009) also stated that 'It has been shown that cover crops can enhance soil nitrous oxide (N_2O) emissions, but the magnitude of increase depends on the quantity and quality of the crop residues'. Li *et al.,* (2014) state that N_2O emissions from legume based catch crops are similar to those from fallow land and non-legume based catch crops.

Gomes *et al.,* (2009) state that an increase in N_2O emissions is seen in the short term following cover crop management. This is supported by Brozyna *et al.,* (2013): 'Periods of high N_2O emissions coincided with cover crop and grass-clover residue turnover'.

N_2O emissions from this measure are generally greater following tillage in the spring (Brozyna *et al.,* 2013; Li *et al.,* 2014); however, peak N_2O emissions occur at different times depending on the catch crop (Li *et al.,* 2014). Higher emissions from cover cropped areas are also seen after freezing events (Petersen *et al.,* 2011). However, the amount of N_2O emissions stimulated following spring cultivation can be reduced through the use of reduced tillage; this may be a method for reducing any small increases in GHG emissions (Petersen *et al.,* 2011).

It is thought that the application rate of N will determine whether cover crops will have an impact on N_2O emissions (Jarecki *et al.,* 2009).

Table 27: Summary of influencing factors for using cover/catch crops

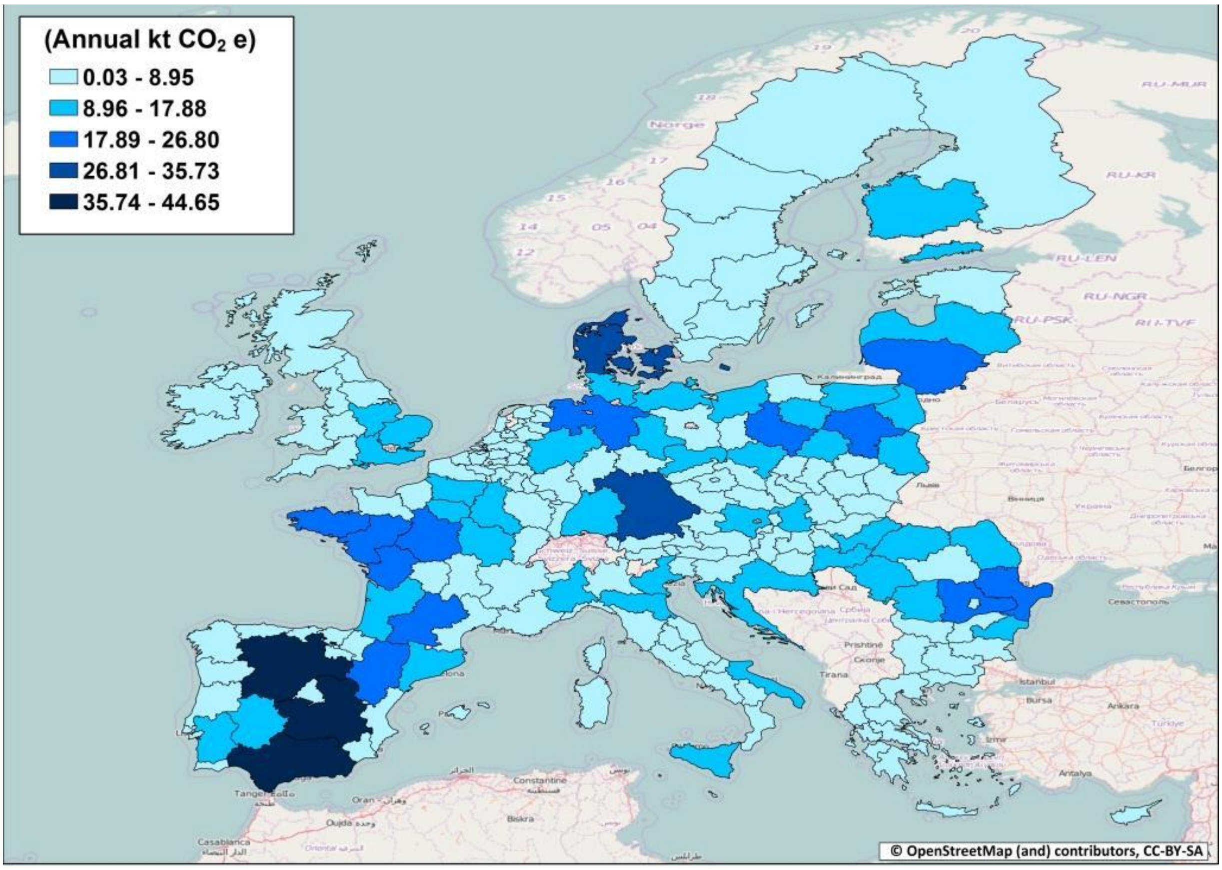
Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Many arable crops in rotational arable (cropland) systems.
Which soil types is this MA relevant to?	Any.
Which climatic zones is this MA relevant to?	Any.

Values

Poeplau and Don (2015) used data from 139 plots at 37 different sites to determine that cover crops significantly increased SOC in comparison with reference croplands and that this increase in SOC persists beyond the length of the cover crop introduction; They found a mean annual SOC sequestration of 0.32 +/- 0.08 Mg ha^{-1} yr^{-1} to an average maximum increase of 16.7 Mg ha^{-1}'. From this study we used a range of 0.88 to 1.47 t CO_2e sequestered in soil per ha per year, using the the upper and lower confidence intervals reported.

The mitigation potential at NUTS 2 level (kt CO_2e/y) is shown in Figure 25.

Figure 25: Mitigation potential at NUTS 2 level, kt CO_2e/y



Environmental co-benefits and risks of the MA

There are other environmental benefits of this action, additional to the effect on GHG emissions. These benefits could include:

- cover/catch crops can reduce exposure of the soil surface and thus can help to reduce soil erosion by wind and water and;
- benefits for water quality from reduced nitrate leaching;
- possibly improved soil moisture status (but in drier areas the catch/cover crops may lead to an increased requirement for water, compared to bare fallow)

There are also risks to the environment from implementing the action and to GHG emissions as a result of the changes to production. These risks could include:

- decreased water quality if herbicides are used to remove the crops;
- if the use of cover/catch crops reduces the yield of the following crop there may be a risk of production displacement, leading to increased production elsewhere, possibly in regions where GHG emissions per tonne of crop produced are greater than in the EU;
- negative impacts on farmland biodiversity resulting from the loss of bare fallow habitats.

Technological and socio-cultural barriers

There should be no technological or other barriers to the use of cover/catch crops, but technical support from a farm advisor may be required to select carefully a cover/catch crop appropriate for the farm, as the balance of costs/benefits differs widely (SmartSOIl, 2015).

Costs/business benefits to land managers of implementing the MA at farm/forest level

This action involves a change to the cropping system and there will be additional costs associated with cultivation of the catch/covercrop, compared to bare fallow, as well as potential agronomic benefits (e.g. to soil quality) and possibly additional income from the crop. At farm level the change in gross margin depends on whether the cover/catch crop is implemented during the winter or spring, what kind of crop is used (e.g., legume, rye) as these may have varying yield impacts, and the region under consideration (SmartSOII, 2015).

A recent study found a wide range of economic effects from using catch/cover crops. The researchers tried to establish average values for the EU, taking into account that gross margin impacts depend on whether high, middle or low yield scenarios are considered. The study concluded that adding cover/catch crops may increase gross margin by €16.60 /ha or decrease gross margin by €270 /ha, but on average it is estimated that gross margin in the short term will decrease by €174.50 /ha. (SmartSOII, 2015).

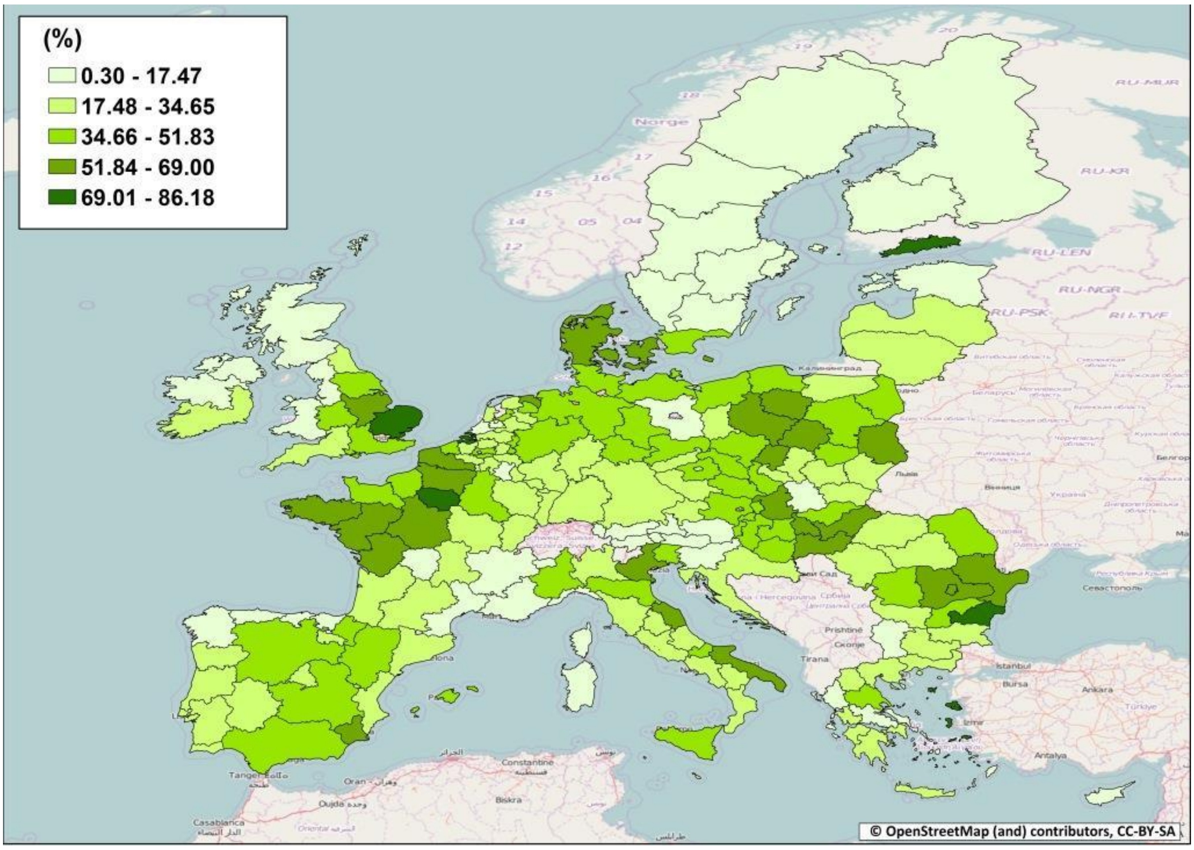
Farmers could choose to implement this climate mitigation action in the short-term (before 2020), but individual decisions will be influenced by the economic impact on the farm business and possibly other factors.

Geographic relevance

The use of cover/catch crops is related to arable land. ‘Cover crops are widely applicable on different soil types in arable rotations; however, they are best suited to light soils types, due to the spring ploughing requirement, and light-textured free-draining soils to enable preparation of a good seedbed for the succeeding crop’ (Frelih-Larsen *et al.,* 2014). Therefore this action will be most effective in areas with a large area of annual crop production and with light-textured free-draining soils.

The percentage of land currently in arable production systems at NUTS 2 level is shown in Figure 26.

Figure 26: Land in arable production as a percentage of total area for each NUTS 2 region



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 28.

Table 28: Summary of reporting issues for using cover/catch crops

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes The mechanisms through which this action may mitigate GHG emissions include change in soil organic carbon content and change in emissions of N_2O from soil. However, these mechanisms may or may not influence the national inventories because of availability of activity data.
Is there a methodology that will show specific impact of the mitigation action? What is it?	Yes For direct N_2O emissions: Vol 4, Ch 11, Section 11.2. Tiers 1, 2 and 3 can all be used; the accuracy increases with tier. Tier 1: gives a simple linear relationship between the amount of N_2O emissions and the amount of nitrogen applied. More specific emission factors are used in tiers 2 and 3, improving accuracy. For indirect N_2O emissions: Vol 4, Ch 11, Section 11.2.

	Tiers 1, 2 and 3 can all be used; the accuracy increases with tier. Tier 1: gives a simple linear relationship between the amount of N_2O emissions and the amount of nitrogen applied. More specific emission factors are used in tiers 2 and 3, improving accuracy. For soil carbon stock change: Refer to 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Vol 4, Ch 5 (cropland), 5.17, section 5.2.3.2, Table 5.5, stock change factors. Tier 1: The effect of the Mitigation Action is detectable, divided into pools: biomass, dead OM, soil carbon. Uses default figures. Tier 2: Relies on some country-specific estimates of the biomass in initial and final land uses rather than the defaults, as in Tier 1. Includes transfer between carbon pools, which changes the emissions total. Tier 3: Increases the accuracy but also has increased costs. Requires countries to have country-specific emission factors, and substantial national data.
Categories	Direct N_2O emissions from managed soils Indirect N_2O emissions from managed soils Cropland remaining Cropland
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Agricultural soils Cropland remaining Cropland
Which Member States included this as a Key Category in their 2014 National Inventory Reports	Agricultural soils, direct 27 MSs: AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,FR,HR,HU,IE,IT,LT,LU,LV,MT,NL,PL, PT,RO,SE,SI,SK,UK Agricultural soils, indirect 27 MSs: AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,FR,HR,HU,IE,IT,LT,LU,LV,MT,NL,PL, PT,RO,SE,SI,SK,UK ,Cropland remaining Cropland 21 MSs: AT,CZ,DE,DK,EE,EL,ES,FI,FR,HR,HU,IT,LT,LU,LV,PL, RO,SE,SI,SK,UK
Tiers used	Agricultural soils, direct Tier 1: 23 MSs AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,HR,IT,LT,LU,LV,MT,PL,PT, RO,SE,SI,SK,UK Tier 2: 5 MSs ES,FR,HU,IE,NL Tier 3: 0 MSs

	Not specified or not applicable: 0 MSs Agricultural soils, indirect Tier 1: 23 MSs AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,HR,IT,LT,LU,LV,MT,PL,PT, RO,SE,SI,SK,UK Tier 2: 5 MSs ES,FR,HU,IE,NL Tier 3: 0 MSs Not specified or not applicable: 0 MSs Cropland remaining Cropland Tier 1: 16 MSs CZ,DE,EE,EL,FI,HR,IE,IT,LT,LU,LV,MT,PL,RO,SI,SK Tier 2: 3 MSs AT,ES,FR,HU Tier 3: 2 MSs SE,UK Not specified or not applicable: 7 MSs
Limitations of the Inventory reporting structure	The main limitation is the accuracy of activity data, specifically the area of land to which this action is applied.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

The measure level reports and analyses of the 2007 to 2013 RDPs are too broad brush to permit identification of this climate mitigation action and no summary information is available on the 2015 to 2020 RDPs.

The most significant policy change in 2015 was the introduction of greening requirements with the opportunity for Member States to offer catch crops or green cover as an EFA choice for farmers. This EFA element was offered as a choice for farmers in 19 Member States (but not in Estonia, Greece, Spain, Italy, Cyprus, Lithuania, Malta, Portugal, Finland, or in Northern Ireland and Wales in the UK). It is important to note that uptake of this EFA option at farm-level is not yet known and will not necessarily be linked to the introduction of catch crops or green cover in an arable rotation, because existing use can count towards EFA requirements.

There is a degree of flexibility in relation to the rules that are put in place to inform Member States how some EFA elements are to be implemented in practice. For example, for catch crops/green cover Member States have a choice to make about the types of crops permitted, as well as where, when and how they can be grown (i.e. whether fertilizers and pesticides are permitted and when the crops must be in the ground). These rules will have an impact on the degree to which their climate mitigation potential is realised in practice.

Where it is appropriate to promote this action, and the requirements for verification and control can be met, the relevant CAP measures could include:

- under Pillar 1 greening requirements, crop diversification and use of N-fixing crops as EFAs

- demonstration activities and information (M 1.2)
- agri-environment-climate payments, as equivalence for EFAs (M10.1)

References

Abdalla M, Hastings A, Helmy M, Prescher A, Osborne B, Lanigan G, Forristal D, Killi D, Maratha P, Williams M, Rueangritsarakul K, Smith P, Nolan P and Jones M.B (2014) Assessing the combined used of reduced tillage and cover crops for mitigating greenhouse gas emissions from arable ecosystem, *Geoderma*, 223-225, 9-20.

Brozyna M.A, Petersen S.O, Chirinda N and Olesen J.E (2013) Effects of grass-clover management and cover crops on nitrogen cycling and nitrous oxide emissions in a stockless organic crop rotation, *Agriculture, Ecosystems and Environment*, 181, 115-126.

EIP-AGRI (2015) Focus Group Soil Organic Matter in Mediterranean regions, Final Report March 2015.

Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu, J.L., Lasorella, M.V. and Longhitano, D. (2014) "Mainstreaming climate change into rural development policy post 2013." Final report. Ecologic Institute, Berlin.

Gomes J, Bayer C, de Souza Costa F, de Cassia Piccolo M, Zanatta J.A, Vieria F.C.B and Six J (2009) Soil nitrous oxide emissions in long-term cover crops-based rotations under subtropical climate, *Soil & Tillage Research*, 106, 36-44.

Jarecki M.K, Parkin T.B, Chan A.S.K, Kaspar T.C, Moorman T.B, Singer J.W, Kerr B.J, Hatfield J.L and Jones R (2009) Cover crop effects on nitrous oxide emission from a manure-treated Mollisol, *Agriculture, Ecosystems and Environment*, 134, 29-35.

Li X, Petersen S.O, Soresen P and Olesen J.E (2014) Effects of contrasting catch crops on nitrogen availability and nitrous oxide emissions in an organic cropping system, *Agriculture, Ecosystems and Environment*, 199, 382-393.

Petersen S.O, Mutegi J.K, Hansen E.M and Munkholm L.J (2011) Tillage effects on N_2O emissions as influenced by a winter cover crop, *Soil Biology and Biochemistry*, 43, 1509-1517.

Poeplau C and Don A (2015) Carbon sequestration in agricultural soils via cultivation of cover crops – A meta-analysis, *Agriculture, Ecosystems and Environment*, 200, 33-41.

Pronk,A.A, Bijttebier J., Ten Berge, H.,RuysschaertG., Hijbeek R., Rijk, B., Werner M., Raschke I., Steinmann, H.H., Zylowska, K.,Schlatter N., Guzmán G., Syp A., Bechini L., Turpin N., Guiffant N.,Perret, E., Mauhé, N., Toqué, C., Zavattaro L., Costamagna C., Grignani, C., Lehninen, T., Baumgarten, A.,Spiegel, H., Portero, A.,Van Walleghem, T.,Pedrera, A., Laguna, A., Vanderlinden, K.,Giráldez, V., Verhagen A. (2015) Compatibility of Agricultural Management Practices and Types of Farming in the EU to enhance ClimateChange Mitigation and Soil Health List of Drivers and Barriers governing Soil Management by Farmers, including CostAspects Catch-C project Deliverable 4.434 http://www.catch-c.eu/deliverables/D4.434_List_Drivers_Barriers.pdf

SmartSOIL(2015) SmartSOIL Factsheet: Boosting on-farm soil organic matter with cover/catch crops, http://smartsoil.eu/fileadmin/www.smartsoil.eu/WP5/Factsheets/SmartSOIL_facksheet_cover-crops_final2.pdf

Livestock disease management

Description

Mode of action

Livestock diseases that cause long-term impairment of health may indirectly increase GHG emissions from livestock production due to reduced performance decreasing output and hence increasing the ratio between emissions and output, leading to greater GHG emissions per tonne of produce. Lameness, mastitis, infertility in cattle and calf pneumonia are among the most common conditions that can, if not correctly and promptly treated, cause considerable production losses. The assessments of effectiveness of available controls are variable, probably due to the multi-factorial nature of the conditions and the criteria adopted to define success. However, it is generally agreed that some improvements to the incidence and/or severity of these conditions are possible on most dairy farms. Moreover, it may be the case that larger production units are better able to implement such improvements due to the economies of scale enabling greater investment in monitoring stock health and responding to problems.

This mitigation action is considered with respect to its potential for reducing emissions of primarily CH_4 but also N_2O.

Mitigation potential

Influencing factors

Emission reductions will depend on the specific disease, the efficacy of the intervention and the extent to which this operation encourages uptake of the disease intervention (Frelih-Larsen *et al.,* 2014).

The effectiveness is likely to vary considerably depending upon the current state of herd health.

Table 29: Summary of influencing factors for livestock disease management

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Ruminant livestock systems.
Which soil types is this MA relevant to?	N/A
Which climatic zones is this MA relevant to?	N/A

Values

Potential emission reductions were reported by Frelih-Larsen *et al.,* (2014) to range from a 1.5% reduction from the beef herd to a 22% reduction in emissions intensity for sheep in Scotland. Since there are several livestock health issues that can be potentially addressed via this mitigation action, either individually or together, there is great uncertainty over the potential effectiveness of this mitigation action. There are also relatively few published reports of emission reductions achieved. We therefore took a deliberately conservative view of the potential upper end of the range and a conservative view of the lower end of the range as well.

There will be a very wide range of abatement potentials arising from the adoption of this MA depending upon current stock health and the disease(s) to be reduced. The estimates of mitigation below were derived from the range of mitigation potentials reported in studies reviewed for this project.

We used a range of 1 to 10% of baseline emissions, where the baseline is CH_4 emissions from enteric fermentation (0.03 to 28.20 Mt CO_2e), and all GHG emissions from manure management (0.03 to 15.08 Mt CO_2e) in the 2012 national inventory reports (2014 submission). Although emissions occur in these categories, the effect of the mitigation action will not be shown in NIRs (see section below on "Reporting of the mitigation effect").

The mitigation potential at Member State level (kt CO_2e/y) is shown in Figure 27. The mitigation potential at Member State level per 1000 head of livestock is shown in Figure 28.

Figure 27: Mitigation potential at Member State level, kt CO_2e/y

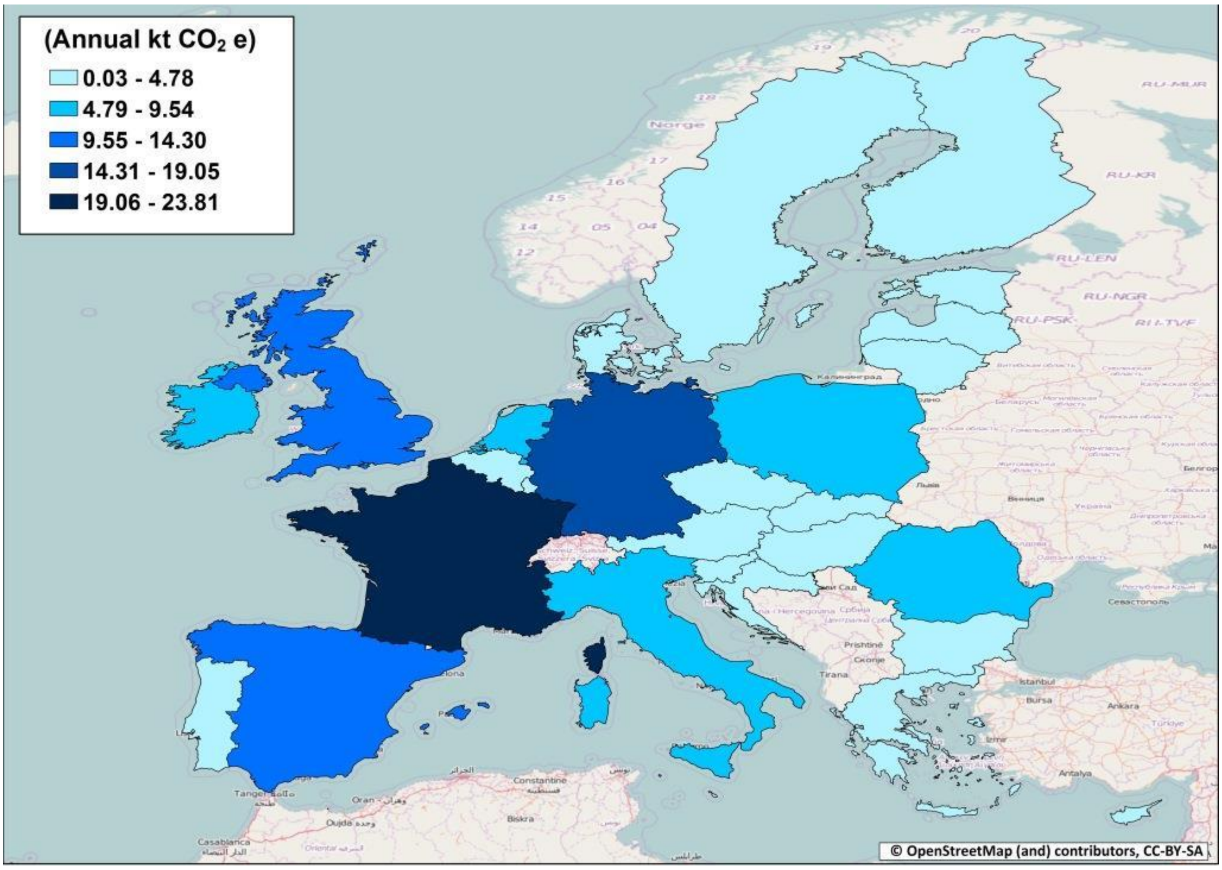
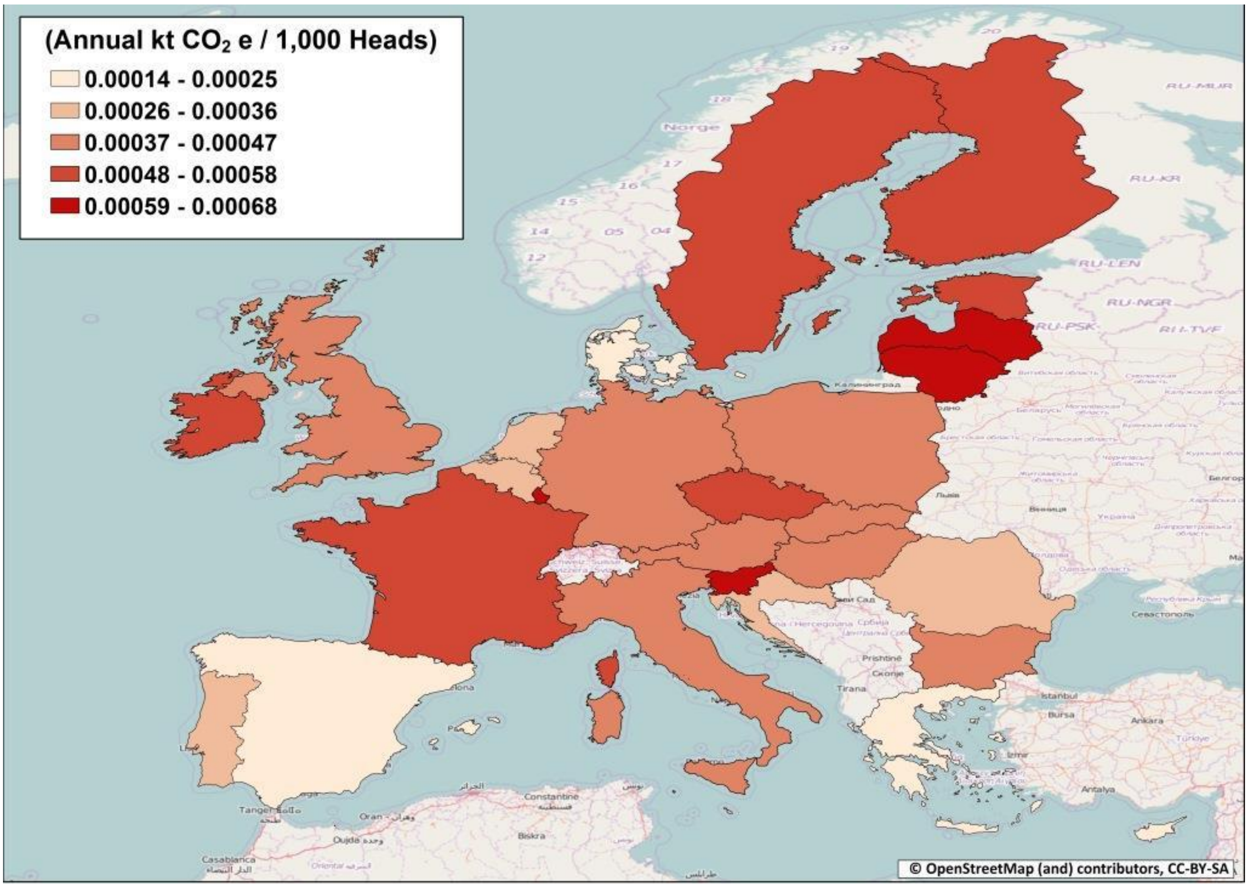


Figure 28: Mitigation potential at Member State level per 1000 head of livestock



Environmental co-benefits and risks of the MA

Improving livestock health is unlikely to lead to any environmental benefits or risks in addition to the climate mitigation benefits from increased efficiency of production.

Technological and socio-cultural barriers

Although the techniques for improving disease management are well understood by veterinary professionals, not all farmers will necessarily be aware of the options or recognise the opportunities to use them. Implementation at farm level depends on the farmer being able to identify that a health problem exists and being willing to call on veterinary services to resolve it.

Costs/business benefits to land managers of implementing the MA at farm/forest level

Improved management of livestock disease incurs recurrent costs, including veterinary services and advice. For some interventions these costs may to some extent be offset by improvements in productivity and business efficiency, for example where improvements in the health of dairy herds leads to increased milk yields. Other interventions will be a net cost to the business.

Farmers could choose to implement this climate mitigation action in the short-term (before 2020), but individual decisions will be influenced by the economic impact on the farm business and possibly other factors, including the herdsman's skill and motivation to improve livestock health.

Geographic relevance

The relevance of livestock disease management as a climate mitigation action is related to livestock density. Livestock density by Member State is shown in Figure 29. Livestock density by NUTS 2 level is shown in Figure 30.

Figure 29: Livestock density by Member State

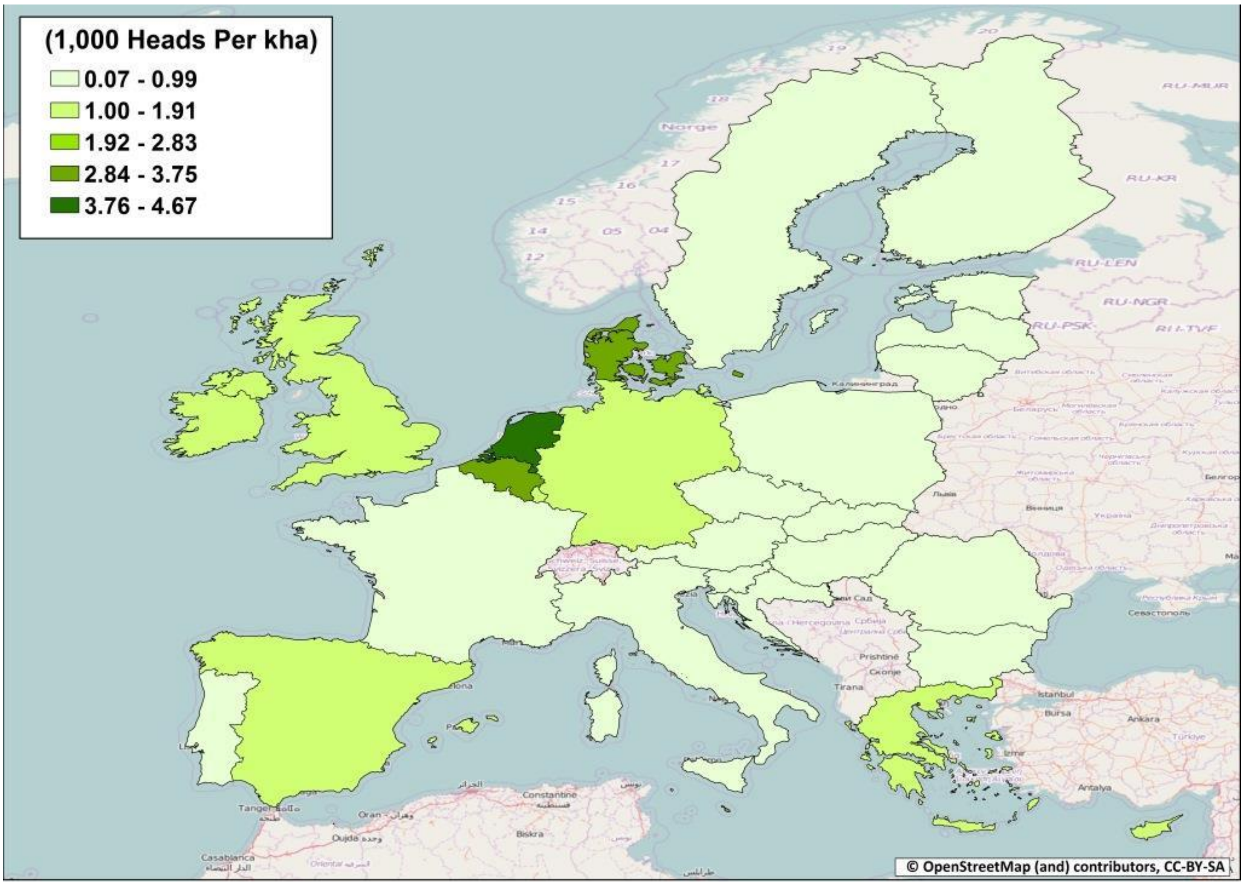
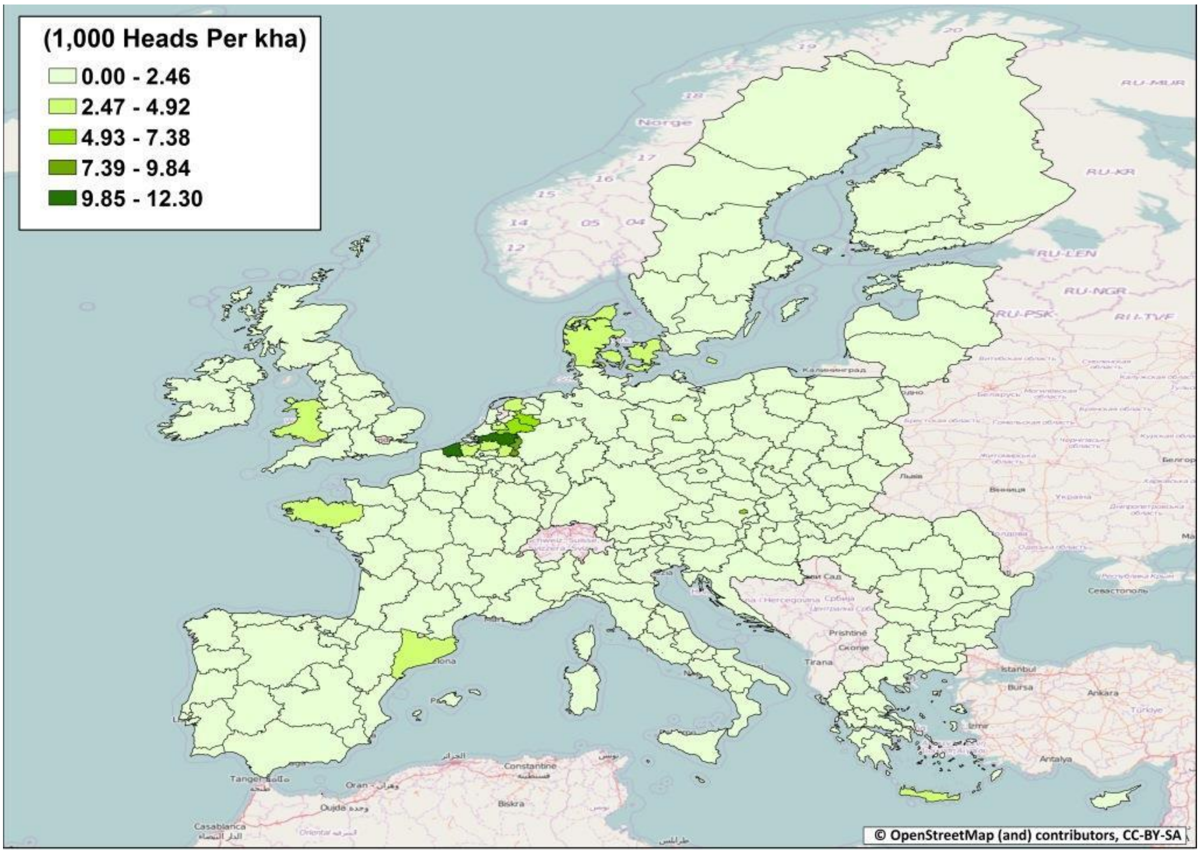


Figure 30: Livestock density by NUTS 2 level



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 30.

Table 30: Summary of reporting issues for livestock disease management

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	The inventory may be partially sensitive to disease reduction but this would only be on the basis that animals produce less methane or there are less animals. Both scenarios could theoretically occur as animals could be more productive e.g. finished earlier, produce more milk or produce more progeny. Despite the potential positive impacts, accounting for this would be very challenging. Firstly identifying the impact of improved disease management on increased productivity within the activity data will not be possible. But the main issue is that the improved productivity does not necessarily lead to a reduction in emissions unless the market demand for a product remained static which would be a false assumption as the market will react to price triggered by supply variation.

	Disaggregating the impact of an improved disease status in the inventory would be exceedingly challenging and at present no member states are equipped to do so.
Is there a methodology that will show specific impact of the mitigation action? What is it?	Using a tier 3 approach a member state can create its own methodology. But even then it may not pick this up. The cost associated with tier 3 is likely to be high. There would need to be an action for every endemic disease as they would have different emissions factors.
Categories	Enteric Fermentation
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	N/A The impact of this mitigation action is not shown in any category of the 2014 submission of National Greenhouse Gas inventories because activity data and appropriate methodologies are not available.
Which Member States included this as a Key Category in their 2014 National Inventory Reports	N/A
Tiers used	N/A
Limitations of the Inventory reporting structure	The impact of improved disease management on increased productivity is not possible with available activity data. The improved productivity does not necessarily lead to a reduction in emissions unless the market demand for a product remains static which would be a false assumption as the market will react to price variation triggered by supply variation.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

No examples were found of CAP support for improved management of livestock disease (going beyond the cross-compliance requirement of SMR 9[25]), but it is possible that this may have been promoted through RDP-funded government advisory services. In some Member States there may be links with government programmes to improve herd and flock health and eradicate endemic diseases.

Where it is appropriate, the relevant CAP measures to promote improved management of livestock disease include:

- demonstration activities and information (M 1.2)

[25] Relating to the prevention, control and eradication of certain transmissible spongiform encephalopathies (Article 93 and Annex II of Regulation (EU) 1306/2013

- setting up farm and forestry advisory services (M 2.2) to provide through the Member State's Farm Advisory Service information on: GHG emissions of the relevant farming practices; on the contribution of the agricultural sector to mitigation through improved farming and agroforestry practices; and on how to improve and optimise soil carbon levels[26];
- possibly EIP operational groups and pilot projects (M 16.2).

Reference

Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu, J.L., Lasorella, M.V and Longhitano, D (2014) "Mainstreaming climate change into rural development policy post 2013." Final report. Ecologic Institute, Berlin.

[26] This information is an option for Member States, not a required part of the Farm Advisory Service. Article 12.3 and Annex 1 of Regulation (EU) 1306/2013

Use of sexed semen for breeding dairy replacements

Description

Sexed semen (90% X-sorted) will alter the ratio of heifer to bull calves from 50:50 to 90% heifer calves and 10% bull calves (Teagasc, 2014). Sperm can be sorted because sperm containing an X-chromosome (female offspring) contain approximately 4% more DNA than sperm containing a Y-chromosome (male offspring).

Mode of action

This mitigation action is considered with respect to its potential for reducing emissions of CH_4.

Dairy cows need to give birth to produce milk. However, a dairy cow completing n lactations requires only *c*. 1/n viable heifer calves to maintain the dairy herd. In practice, slightly more than 1/n are needed as some heifers are infertile. As a result the majority of the n calves born (males plus surplus females) may be sold to beef producers to be raised for meat. However, modern dairy breeds such as Holsteins are not considered to be well conformed to be raised as beef cattle. If this situation could be improved, the sourcing of calves from the dairy sector has the potential to reduce GHG emissions from beef production by reducing the need for suckler cattle.

In summary, use of sexed semen results in fewer calves from dairy bull semen (because most are female, so fewer calves are needed to provide dairy cow replacements), and a higher proportion of calves are sired by beef bulls, giving dairy-beef crossbred cattle and more efficient meat production.

Mitigation potential

Influencing factors

Relative to the number of sperm required for each AI straw, sperm sorting is slow. As a result, the number of sperm per sexed semen AI straw is only 10% of that in conventional AI straws (2 million sperm vs. 20 million sperm). Due to a combination of the lower dose and unavoidable sperm damage sustained during the sorting process, the fertility of sexed semen is reduced compared with conventional semen. Previous studies in the USA have found a reduction in conception rates using frozen sexed semen of approximately 75 to 80% of those achieved with conventional semen. A study in New Zealand using fresh sexed semen indicated conception rates were approximately 94% of those achieved with conventional semen.

Table 31: Summary of influencing factors for use of sexed semen for breeding dairy replacements

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Livestock - Dairy
Which soil types is this MA relevant to?	N/A
Which climatic zones is this MA relevant to?	N/A

Values

There are only two estimates of the mitigation potential of this mitigation action. The lower estimate is from Webb *et al.,* (2014) who concluded that sexing semen, even if 100% successful, only achieves a 1% decrease in GHG emissions from beef production. The upper estimate, made during the course of this project was taken from the update of the UK MACC for GHG mitigation from agriculture.

We used a range of 1 to 3.5% of baseline emissions, where the baseline is CH_4 emissions from enteric fermentation and all GHG emissions from manure management in the 2012 national inventory reports (2014 submission).

The mitigation potential at Member State level (kt CO_2e/y) is shown in Figure 31. The mitigation potential per 1000 head of cattle by Member State is shown in Figure 32.

Figure 31: Mitigation potential at Member State level, kt CO_2e/y

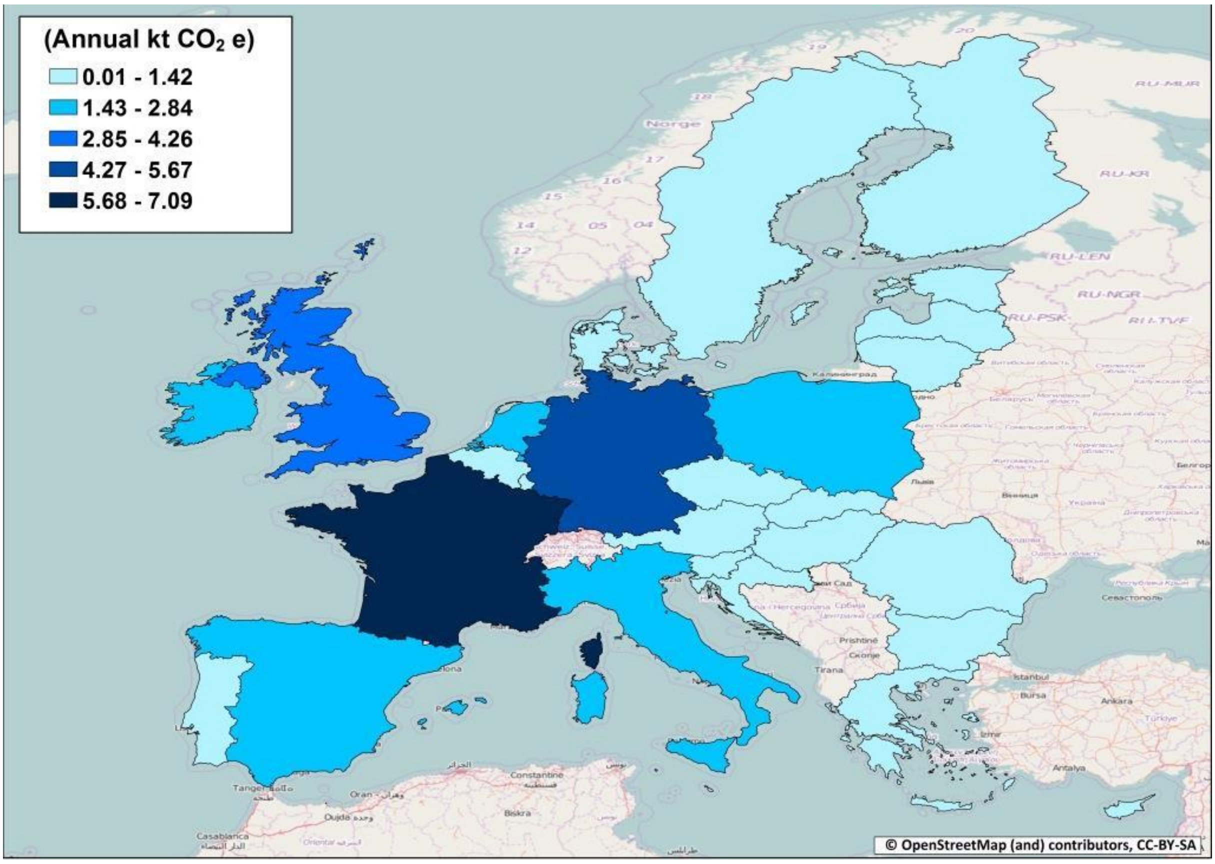
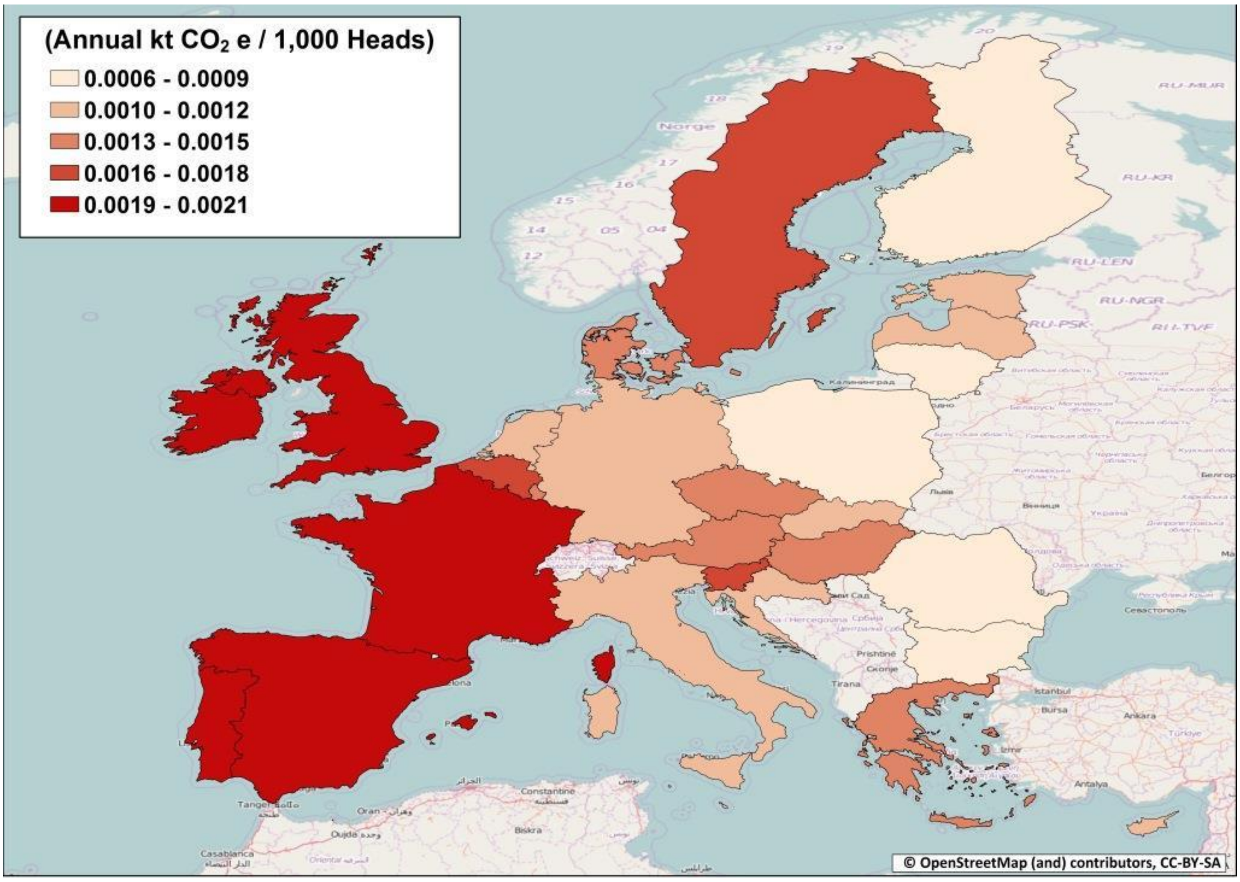


Figure 32: Mitigation potential per 1000 head of cattle by Member State



Environmental co-benefits and risks of the MA

Use of sexed semen for breeding dairy replacements is unlikely to lead to any environmental benefits or risks in addition to any climate mitigation benefits from increased efficiency of meat production.

Technological and socio-cultural barriers

The technology is available as a commercial veterinary service for dairy farms.

Costs/business benefits to land managers of implementing the MA at farm/forest level

Using sexed semen for breeding dairy replacements is relatively expensive. Although it improves the quality of beef calves produced from the dairy herd and may reduce the number of calves sent for immediate slaughter, it does not alter the proportions of beef/dairy calves that the herd produces. It may also reduce incidence of calving difficulty (because heifer calves are lighter than bull calves) and improve biosecurity by allowing farmers to increase herd size while maintaining a closed herd (Teagasc, 2014).

Farmers could choose to implement this climate mitigation action in the short-term (before 2020), but individual decisions will be influenced by the economic impact on the farm business and possibly other factors.

Geographic relevance

The potential use of sexed semen for breeding dairy replacements will be related to dairy cow density. Dairy cow density by Member State is shown in Figure 33. Dairy cow density by NUTS 2 level is shown in Figure 34.

Figure 33: Dairy cow density by Member State

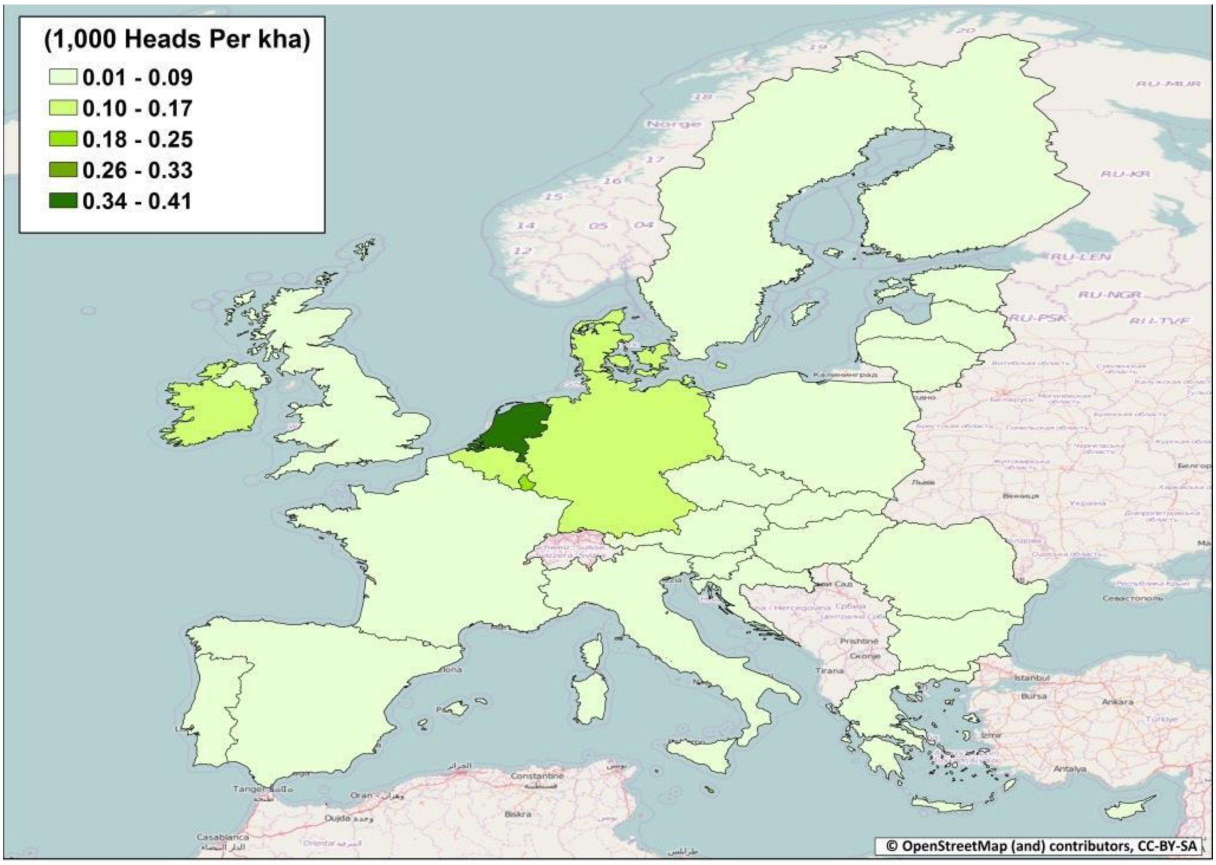
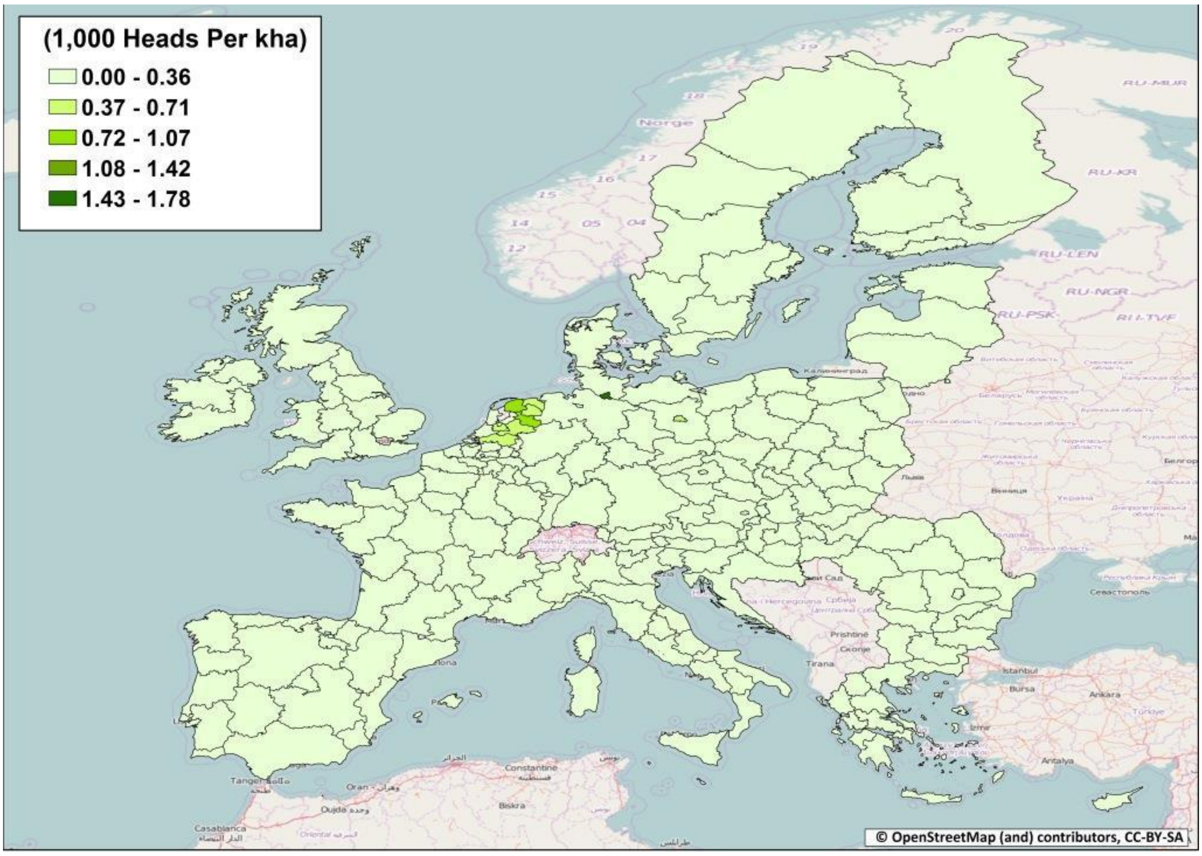


Figure 34: Dairy cow density by NUTS 2 level



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 32.

Table 32: Summary of reporting issues for use of sexed semen for breeding dairy replacements

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	No. This is an efficiency measure that could theoretically lead to a reduction in the beef suckler cow numbers as an indirect impact of the action being adopted. Similarly to the disease reduction action, the assumptions on GHG abatement rely on a static market demand.
Is there a methodology that will show specific impact of the mitigation action? What is it?	No. The inventory will record different numbers of livestock within species and sector groups (beef and dairy). Attributing the fluctuations as a result of increased use of sexed semen would not be possible.
Categories	Possible impacts on enteric fermentation and manure management
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	N/A The impact of this mitigation action is not shown in any category of the 2014 submission of National Greenhouse Gas inventories because activity data and appropriate methodologies are not available.
Which Member States included this as a Key Category in their 2014 National Inventory Reports	N/A
Tiers used	N/A
Limitations of the Inventory reporting structure	It is not practical to obtain activity data. The inventory will record different numbers of livestock within species and sector groups (beef and dairy). Attributing the fluctuations as a result of increased use of sexed semen would not be possible.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

The measure level reports and analyses of the 2007 to 2013 RDPs are too broad brush to permit identification of this climate mitigation action and no summary information is available on the 2015 to 2020 RDPs. One example was found of the use of coupled Pillar 1 funding in Ireland in 2007 to 2013 to improve efficiency of dairy herds (Box 2) although the summary of the scheme did not specifically mention the use of sexed semen.

Box 2 Dairy Efficiency Programme in Ireland

The idea came from a dairy sector group looking at how to achieve the government agri-food strategy. The Dairy Efficiency Programme was funded by CAP Pillar 1 coupled payments measure, used in this case to address specific disadvantages in the dairy sector. Farmers were paid an incentive of €1,000 per year to participate in regular on-farm discussion groups to help them adopt best practice in relation to grassland management, breeding using genomic bulls, and financial management. Each participant had to implement a specified programme of activities on their farms and attended discussion group events. The incentive payment was an encouragement to become involved in the programme and experience showed that participants saw a benefit in continuing with the discussion groups[27].

Where it is appropriate, the relevant CAP measures to promote improved management of livestock disease include:

- demonstration activities and information (M 1.2)

References

Teagasc, (2014) Moorepark dairy Levy Research Update. Breeding Strategies for an Expanding dairy Industry. Series 23, 9 April 2014. http://www.teagasc.ie/publications/2014/3146/Dairygold_Research_Farm_Booklet090414.pdf

Webb J, Audsley E, Williams A, Pearns K and Chatterton J. (2014) Can the UK livestock industry be configured to maintain production while meeting targets to reduce emissions of greenhouse gases and ammonia? *Journal of Cleaner Production,* 83, 204-211.

[27] Source: ENRD Annex 1 - Collection of examples of the Knowledge Transfer & Innovation Focus Group http://enrd.ec.europa.eu/sites/enrd/files/fms/pdf/B16C6E54-95D9-07B8-6EC1-4CA9D6E42519.pdf

Breeding lower methane emissions in ruminants

Description

This mitigation action is to breed ruminants with reduced emissions of CH_4 per tonne of product.

Mode of action

Historically, selection for efficiency of production in ruminant species has also led to reductions in emissions of CH_4. In many cases this has been achieved through selection of production traits and traits related to the efficiency of the entire production system (e.g., fertility and longevity). The impact of selection on these traits is twofold:

- Reducing the number of animals required to produce a fixed amount of output. This leads to a reduction in emissions of CH_4 per kg of meat or litre of milk produced.
- Increasing the efficiency of production will help reduce the finishing period for meat animals, therefore reducing emissions per unit output. Moran *et al.,* (2008) reported that the efficiency of beef production systems was paramount in reducing the GHG emissions per unit output; intensive concentrate based systems produced the least emissions. While this study did not consider the externalities of the system such as the carbon cost of producing concentrate diets, some energy-rich crops, such as forage maize, require substantially less N fertilizer input than conserved grass. There is also a significant breed difference suggesting that bigger breeds of cattle produced less emissions/unit output than the smaller, traditional, breeds.

Mitigation potential

Influencing factors

Defra project AC0204 (Genesis Faraday Partnership, 2008) modelled the effect of genetic improvement on emissions from UK livestock systems using Life Cycle Assessment. This study showed that historic genetic improvement in UK livestock species has had a favourable effect on the overall productivity of livestock species. It has also had a favourable associated effect on the reduction of emissions from many livestock species via improvements in efficiency of the production system. However the impact of genetic improvement in beef cattle and sheep has a far lower penetration rate and the best genetics do not disseminate through all strata of the livestock population.

Table 33: Summary of influencing factors for breeding lower methane emissions in ruminants

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Livestock, ruminant animals
Which soil types is this MA relevant to?	N/A
Which climatic zones is this MA relevant to?	N/A

Values

Improvement in livestock species has resulted in a 0.8 to 1.2% per annum decrease in emissions from species that readily adopt genetic improvements throughout the population (i.e., pigs, poultry and dairy cattle) (Defra Project AC204, Genesis Faraday Partnership, 2008).

We used a range of 0.5 to 1.0% of baseline emissions, where the baseline is CH4 emissions for enteric fermentation (category 4.A) from ruminant species in the 2012 national inventory reports (2014 submission). These estimates were derived from the UK Defra project AC0204 (Genesis Faraday Partnership, 2008).

The mitigation potential at Member State level (kt CO_2e/y) is shown in Figure 35. The mitigation potential per 1000 head of livestock (ruminants only) by Member State is shown in Figure 36.

Figure 35: Mitigation potential at Member State level, kt CO_2e/y.

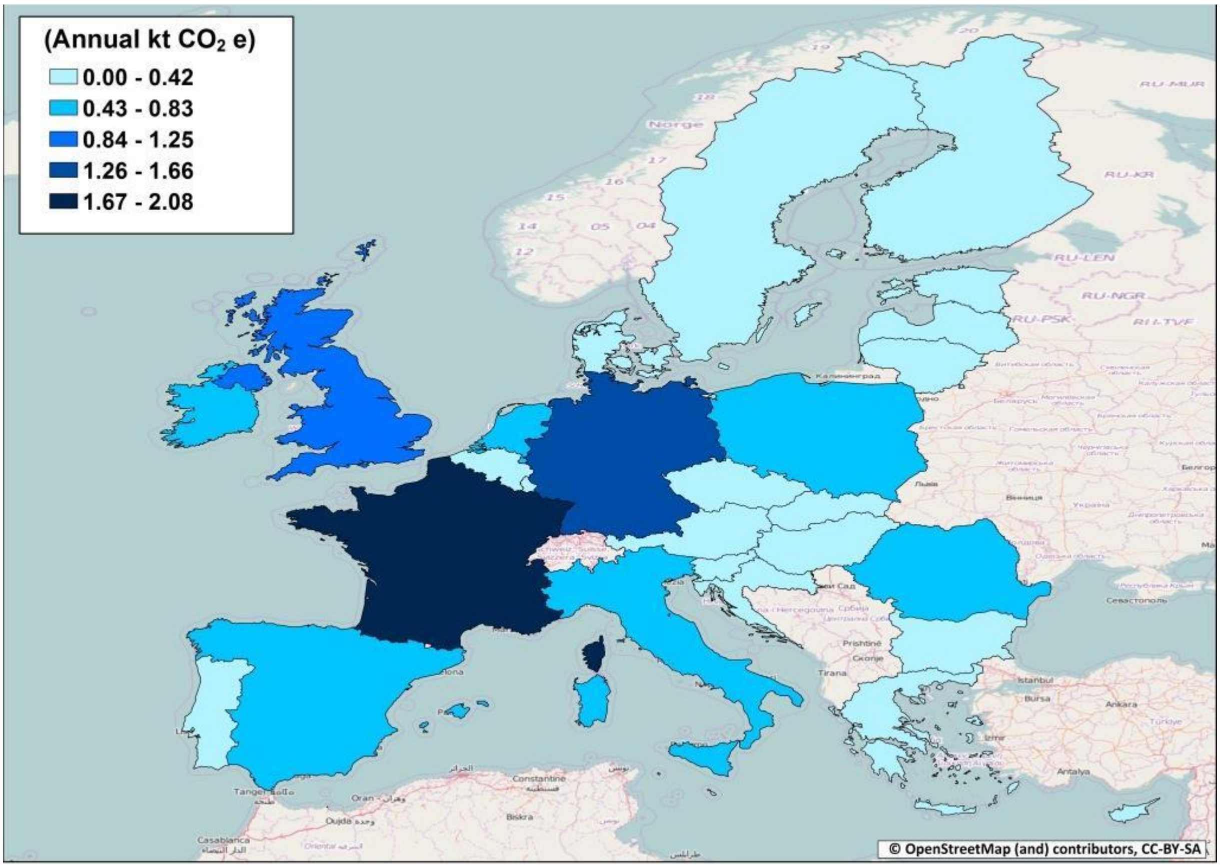
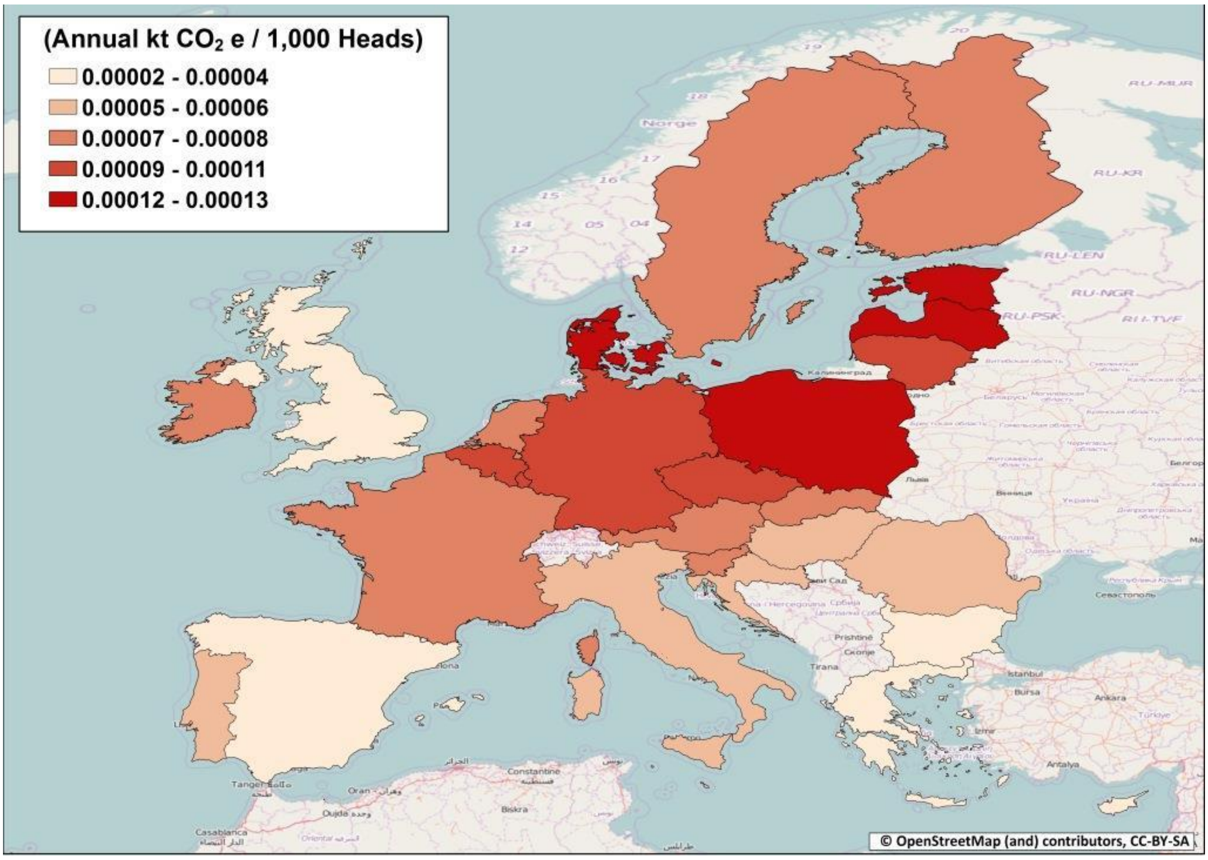


Figure 36: Mitigation potential per 1000 head of livestock (ruminants only) by Member State



Environmental co-benefits and risks of the MA

At this stage in development it is not possible to assess what, if any, other environmental benefits or risks are likely to arise from selectively breeding ruminants for lower methane emissions, in addition to the climate mitigation effects.

Technological and socio-cultural barriers

Breeding programmes for low methane emissions in ruminants have only recently started and there are several technical barriers to be overcome, including maintaining lower levels of methane emissions during the lifetime of the animal as this is also influenced by the microbial population of the rumen, not just the genotype of the animal.

Costs/business benefits to land managers of implementing the MA at farm/forest level

If the breeding programme is successful, the new lower methane breeds are likely to be more expensive than conventional breeds, at least initially. It is impossible to estimate at this stage to what extent these costs may be offset by other economic advantages that may be enhanced during the breeding programme (e.g. more efficient feed conversion or higher yields of meat or milk per head).

It is not possible to estimate the timescale of implementation by farmers because this depends on these improved breeds are becoming commercially available, but this is likely to be in the medium term.

Geographic relevance

The relevance of breeding low methane emissions in ruminants, as a mitigation action, will be related to livestock density. Livestock density (ruminants only) by Member State is shown in Figure 37. Livestock density (ruminants only) by NUTS 2 level is shown in Figure 38.

Figure 37: Livestock density (ruminants only) by Member State

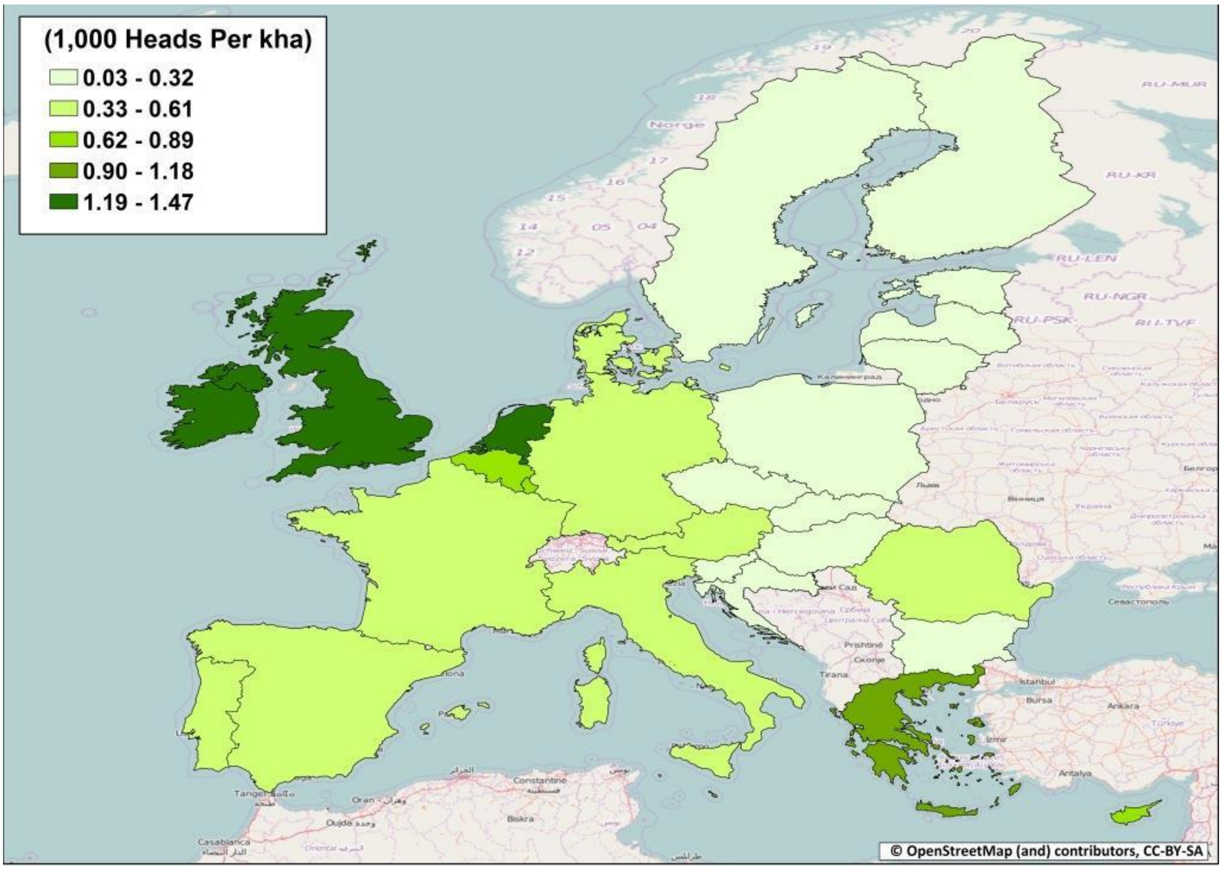
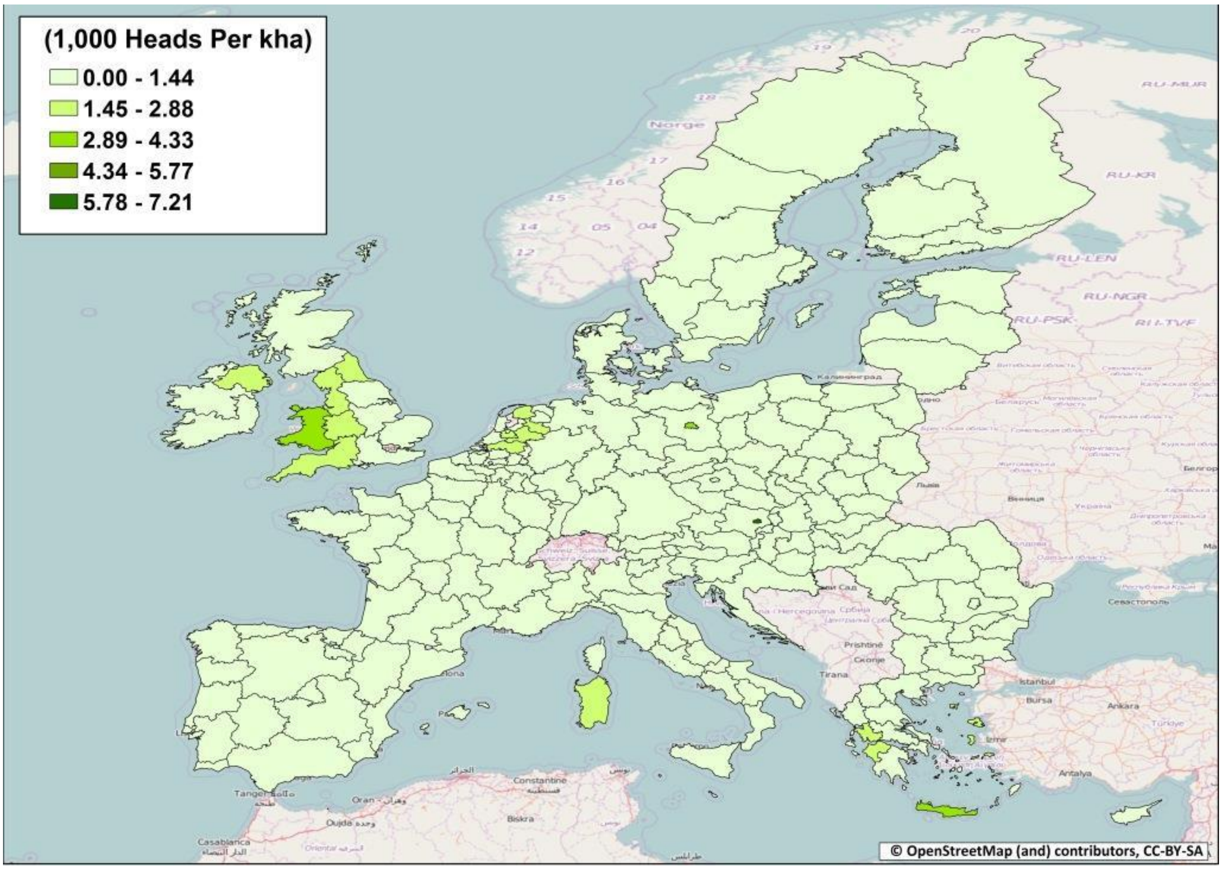


Figure 38: Livestock density (ruminants only) by NUTS 2 level



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 34.

Table 34: Summary of reporting issues for breeding lower methane emissions in ruminants

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes, This will rely on accurate emissions factors for 'low methane ruminants' and accurate activity data.
Is there a methodology that will show specific impact of the mitigation action? What is it?	Yes, As above, it will rely on specific EF's and a specific definition for 'low methane' animals. The alternative is to continually assess the impact of genetic improvement on the entire species population and reduce EF's accordingly. Tier 1: As this uses standard EFs. This will not assess the impact of low emissions animals. Tier 2: Allows for nationally and regionally calculated EF's so would account for changes.

	Tier 3: May increase the accuracy by increasing differentiation between emissions factors and increase. Currently no member states differentiate between 'low methane' animals and standard within species. It is done by weight category.
Categories	Enteric Fermentation
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Enteric Fermentation
Which Member States included this as a Key Category in their 2014 National Inventory Reports	23 member states record Enteric Fermentation as a Key Category. AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,FR,HR,IT,LT,LU,LV,NL, PL,PT,SE,SI,SK,UK
Tiers used	Tier 1: 3 MSs ES,HU,MT Tier 2: 23 MSs AT,BE,BG,CY,CZ,DK,EE,EL,FI,FR,HR,IE,IT,LT,LU,LV,PL,PT, RO,SE,SI,SK,UK Tier 3: 2 MSs DE,NL Not Assessed: 0 MS The tier used in some cases changes according to the species. Many member states use tier 2 approach to calculate emissions from cattle with tier 1 approach for sheep for example.
Limitations of the Inventory reporting structure	Relies on accurate emissions factors for 'low methane ruminants'.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

No examples were found of the use of EU funding to support breeding of low methane emission ruminants, but two countries with significant beef production sectors are introducing new agri-environment-climate schemes in their 2014 to 2020 RDPs aimed reducing emissions from beef production by improving the efficiency of suckler herds through genomics based breeding programmes (Box 3).

Box 3 New agri-environment-climate schemes to reduce emissions from beef production

Ireland is a major beef producer which is launching new Beef Data and Genomics Programme (BDGP) aimed at improving the quality of the Irish suckler beef herd. This is expected to reduce GHG emissions per kg of beef produced because a more efficient suckler cow will, during its lifetime, produce more beef calves of higher quality.

The central element of the BDGP is a large-scale database of detailed information about commercial suckler cow herds which will be used to create a genomics based breeding index that will rank individual animals (5 stars for the most efficient). Farmers will use the index to select the most robust and resource efficient suckler cow and bull replacements.

Farmers participating in this new agri-environment-climate scheme under the 2014 to 2020 RDP are committed to a six-year programme of herd record keeping and genotyping (DNA analysis of individual animals) and must choose herd replacements with a high 'star rating'. They also must use the Farm Carbon Navigator, a decision support tool which estimates the greenhouse gas reductions and financial savings that could be made through improved farm efficiency. This allows individual farmers to set future targets and to compare their farm with average and best performing farms.

The BDGP payment rates are based on the time required for record keeping, the cost of genotyping and the net cost of herd replacements (less any economic benefits from the scheme). A stocking density coefficient is used to convert these 'per animal' costs to an annual hectare based agri-environment-climate payment of €142.50 per hectare for the first 6.66 hectares and €120 per hectare after that. Farmers in the BDGP must undertake a half-day training course about the scheme (for which they are paid €166) and a shorter course on using the Farm Carbon Navigator[28].

Scotland also plans to launch a new Beef Efficiency RDP scheme in 2016, aimed at genetic, economic and environmental improvements in the beef breeding and finishing sector.

There are no relevant CAP measures to support the breeding of low methane emission ruminants.

References

Genesis Faraday Partnership (2008) A study of the scope for the application of research in animal genomics and breeding to reduce nitrogen and methane emissions from livestock based food chains, Defra project AC0204

Moran, D., MacLeod, M., Wall. E., Eory, V., Pajot, G., Matthews, R, McVittie, A., Barnes, A., Rees, B, Moxey, A, Williams, A, Smith, P. (2008). UK Marginal Abatement Cost Curves for the Agriculture and Land Use, Land-Use Change and Forestry Sectors out to 2022, with Qualitative Analysis of Options to 2050. Final Report to the Committee on Climate Change, 20/11/2008, 152 pp.

[28] Source: Department of Agriculture, Food and the Marine (2015) Summary of Rural Development Programme Ireland 2014-20

Feed additives for ruminant diets

Description

This mitigation action is considered with respect to its potential for reducing emissions of CH_4.

There are a several materials which may be added to livestock feeds in order to reduce CH_4 emissions. Such additives may work directly, by reducing the conversion of carbohydrate to CH_4 or indirectly, by improving animal performance and thereby reducing emissions intensity.

Mode of action

Propionate precursors

Hydrogen produced in the rumen through fermentation can react to produce either CH_4 or propionate. By adding propionate precursors (e.g., fumarate) to animal feed, more hydrogen is used to produce propionate and less CH_4 is produced (Moran *et al.,* 2008). Moran *et al.,* (2008) reported that increasing the percentage of propionate at the expense of acetate by 25% reduced CH_4 emissions by *c*. 22%. Milk yield increased by 15%.

Fat supplementation

Increasing the fat content of the diet proportionally reduces enteric CH_4 emissions.

Conventional ruminant diets contain 1.5 to 3% DM fat; the fat content of forages (Frelih-Larsen *et al.,* 2014). Concentrates also typically contain *c*. 2 to 3% fat.

An additional fat supplementation of 2 to 4% fat to increase the total fat content to 5 to 6% was evaluated by Frelih-Larsen *et al.,* (2014). The evaluation reported that some farmers already use supplementary fat in the diets, but there is potential for additional uptake. There are differences among fat sources in terms of their effect on land use and land use change, these differences need to be taken into account.

There are three mechanisms by which fat reduces enteric CH_4 emissions:

- The increased amount of fat replaces other energy sources in the diet, mainly carbohydrates. While carbohydrates are digested in the rumen, fats are digested in the intestine and do not contribute to enteric CH_4 emissions.
- Medium chain fatty acids (e.g. those in coconut and palm kernel oil) and unsaturated fatty acids (e.g. those in linseed, rapeseed, sunflower, soybean) selectively reduce some of the rumen microbes, thus reducing CH_4 emissions. Rumen-protected fat products and long-chain saturated fatty acids do not have these effects.
- Unsaturated fatty acids also act as a hydrogen sink in the rumen, reducing CH_4 production. However, this is a less important effect compared to the other two mechanisms (Frelih-Larsen *et al.,* 2014).

The overall reduction in enteric CH_4 emissions is proportional to the amount of fat in the diet (Frelih-Larsen *et al.,* 2014). However, nutritional and practical aspects impose a limit of 5 to 6% DM total fat content.

Probiotics

Probiotics are microbes used to divert hydrogen from methanogenesis towards acetogenesis in the rumen, resulting in a reduction in CH_4 produced by enteric fermentation. There is an added benefit in that acetate is a source of energy for the animal and therefore can improve overall productivity of the animal. These additives can be used in diets with high grain content. There is variation in the extent to which probiotic additives reduce CH_4 emission. Moran *et al.,* (2008) used an abatement efficiency of 7.5%. They also estimated an improvement in production of 10%.

Ionophores

Ionophore antimicrobials (e.g., monensin) can improve the efficiency of livestock production by decreasing the dry matter intake (DMI) and increasing performance and decreasing CH_4 production (Moran *et al.,* 2008). The effect of these types of feed additives on production and/or CH_4 is variable. Moran *et al.,* (2008) used a reduction in CH_4 emissions of 25% with a 25% improvement in production. This option was studied for beef and dairy cattle.

Mitigation potential

Influencing factors

It should be noted that the use of ionophores is currently forbidden in the EU but they have been routinely used as a growth promoter in some non-EU countries. The urgent need to reduce GHG emissions may lead to the acceptance of ionophores since their use can reduce emissions of CH_4. However, there have been some reports of potential unfavourable side-effects with the application of this treatment with an increase in metabolic disorders in the animal (Moran *et al.,* 2008).

Because the adoption of some feed additives would be difficult, we have estimated the abatement potential for the uptake of feed additives on the basis of the reported abatement for fat supplementation, the best validated of the additives.

Table 35: Summary of influencing factors for feed additives for ruminant diets

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Livestock, ruminant animals
Which soil types is this MA relevant to?	N/A
Which climatic zones is this MA relevant to?	N/A

Values

Increasing the fat content of the diet proportionally reduces enteric CH_4 emissions from cattle by approximately 5% for each 1% increase (i.e. from 2% of dietary intake to 3% dietary intake) in the fat content of the diet (Frelih-Larsen *et al.,* 2014 and references cited therein). Nutritional and practical aspects impose a limit of 5 to 6% of dry matter as total fat content. An upper estimate of 5% reduction in CH_4 emissions was proposed on the assumption that a 1% increase in dietary fat could be realistically achieved; with a lower estimate of 2.5% of CH_4 emissions from an increase in dietary fat of 0.5%.

The decrease in CH_4 emissions for each increase in the proportion of fat in the diet by 1% reported by Frelih-Larsen *et al.,* (2014) was 4.6%. We rounded this value up to 5% and propose the same values for both cattle and sheep.

In summary, we used a range of 2.5 to 5.0% of baseline emissions, where the baseline is the CH_4 emissions total from enteric fermentation in the 2012 national inventory reports (2014 submission).

The mitigation potential at Member State level (kt CO_2e/y) is shown in Figure 39. The mitigation potential per head of livestock (cattle only) by Member State is shown in Figure 40.

Figure 39: Mitigation potential at Member State level, kt CO_2e/y

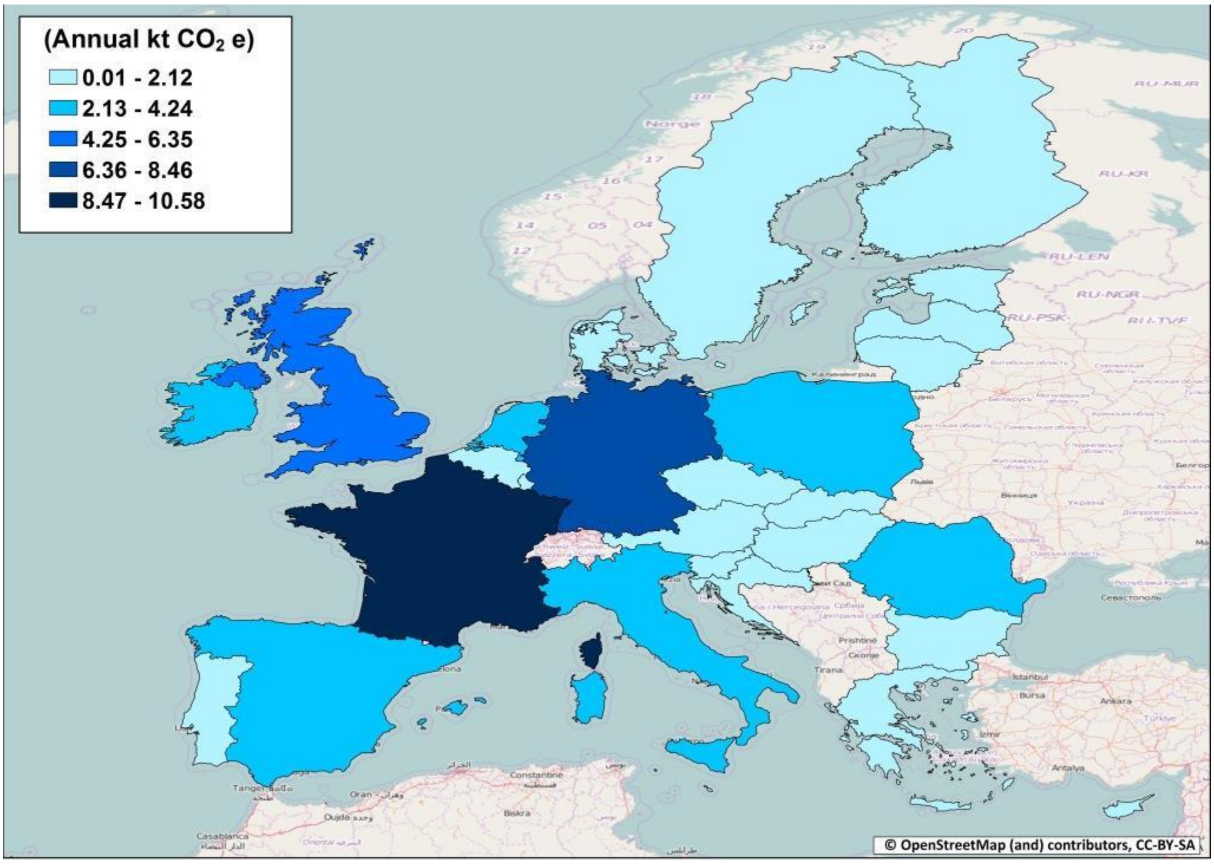
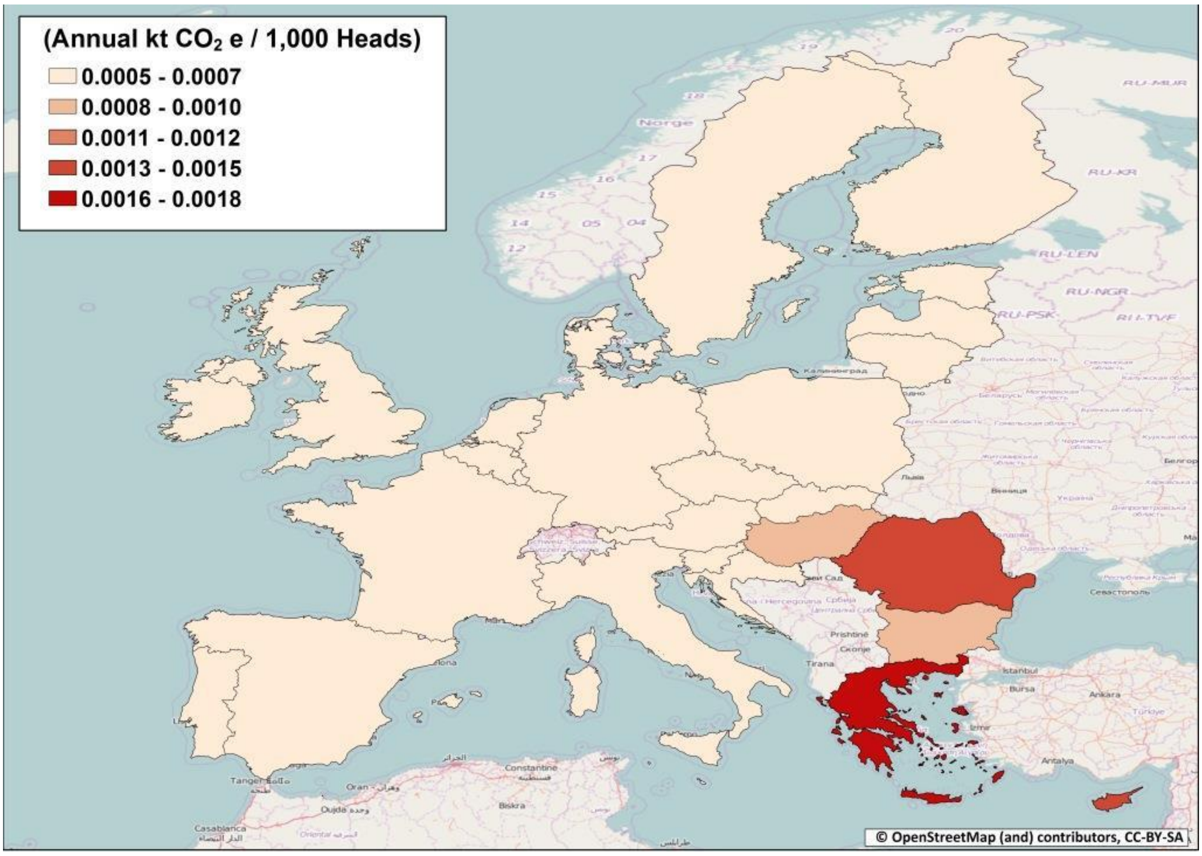


Figure 40: Mitigation potential per head of livestock (cattle only) by Member State



Environmental co-benefits and risks of the MA

There are no other direct environmental benefits of this action in addition to the effect on GHG emissions.

There may also be some risks to GHG emissions as a result of the changes to production. These risks could include:

- large scale use of fat supplements may increase demand for vegetable oils, leading to increased production, possibly in regions where GHG emissions per tonne of crop produced are greater than in the EU.

Technological and socio-cultural barriers

The technology is well developed but some of the feed additives may not be available to farmers. For example, the use of ionophores in livestock feed is currently prohibited in the EU and other additives are not suitable for organic farms. There may also be public concern about using probiotics (microbial inputs) in livestock feed.

Costs/business benefits to land managers of implementing the MA at farm/forest level

Additives are already used by some high productivity beef and dairy units but there is potential for increased uptake by other livestock farmers. On cattle and sheep farms that are more reliant on forage grown on the farm the effective use of additives may require more skilled management because of the variability of the fodder quality.

Improved uptake is likely to require targeting appropriate information at livestock farmers who may not be aware of how to use additives effectively, but the main barrier to uptake is likely to be the cost of the additives, which may not be reflected in improved productivity.

Farmers could choose to implement this climate mitigation action in the short-term (before 2020), but individual decisions will be influenced by the economic impact on the farm business and possibly other factors.

Geographic relevance

Feed additives will be related to livestock density. Livestock density (cattle only) by Member State is shown in Figure 41. Livestock density (cattle only) by NUTS 2 level is shown in Figure 42.

Figure 41: Livestock density (cattle only) by Member State

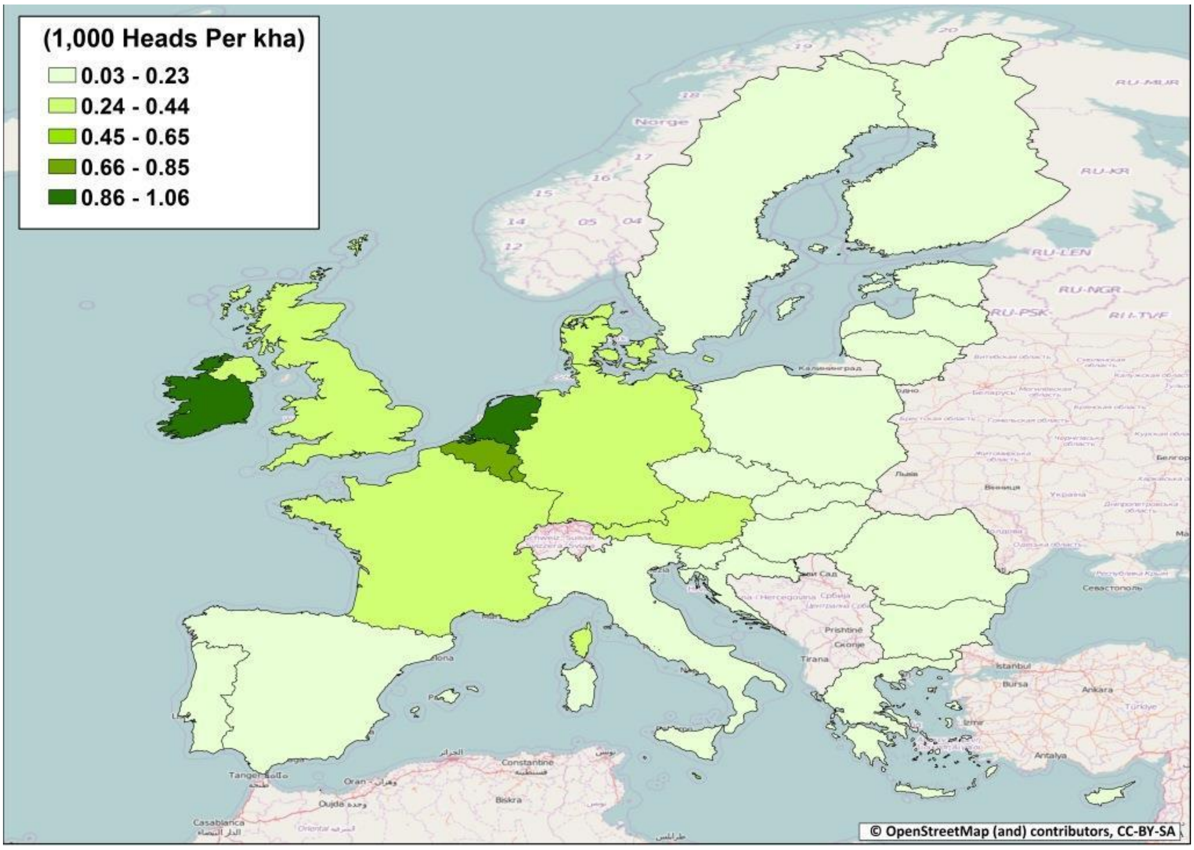
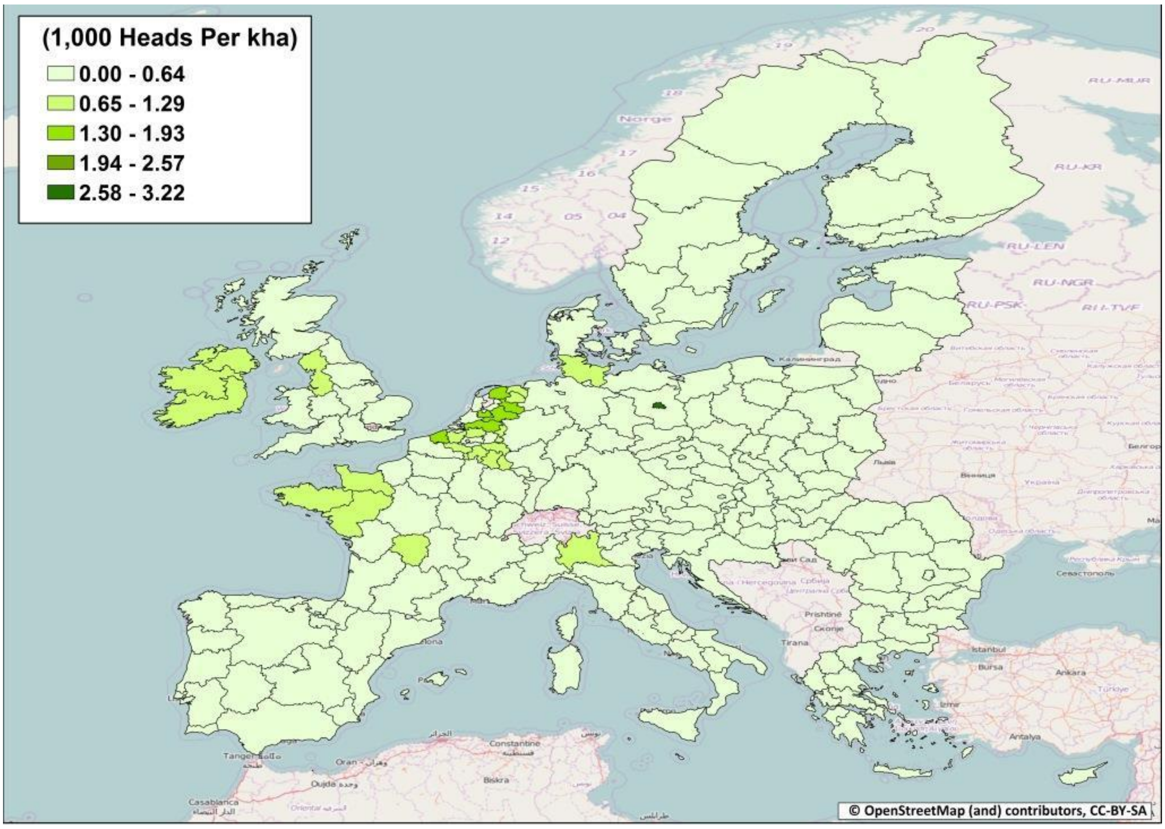


Figure 42: Livestock density (cattle only) by NUTS 2 level



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 36.

Table 36: Summary of reporting issues for feed additives for ruminant diets

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes, This is based on the ability to collect appropriate activity data and Emissions Factors which will be complex are require a tier 3 methodology.
Is there a methodology that will show specific impact of the mitigation action? What is it?	There are No detailed methods detailed within he NIRs reviewed. We believe that an appropriate method could be developed under tier 3. Feed additives comes under effects of digestibility /digestion kinetics.
Categories	Enteric Fermentation
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Enteric Fermentation
Which Member States included this as a Key Category in their 2014 National Inventory Reports	23 member states record Enteric Fermentation as a Key Category. AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,FR,HR,IT,LT,LU,LV,NL, PL,PT,SE,SI,SK,UK
Tiers used	Tier 1: 3 MSs ES,HU,MT Tier 2: 23 MSs AT,BE,BG,CY,CZ,DK,EE,EL,FI,FR,HR,IE,IT,LT,LU,LV,PL, PT,RO,SE,SI,SK,UK Tier 3: 2 MSs DE,NL Not Assessed: 0 MS The tier used in some cases changes according to the species. Many member states use tier 2 approach to calculate emissions from cattle with tier 1 approach for sheep for example.

Limitations of the Inventory reporting structure	Relies on accurate emissions factors for animals fed on different diets and the ability to capture Activity Data relating to dietary variation. Explicitly says in guidance that there is considerable room for improvement

Policy measures that could be or have been used to encourage implementation of the MA in the EU

No examples were found of the use of EU funding to encourage the use of feed additives. The measure level reports and analyses of the 2007 to 2013 RDPs are too broad brush to permit identification of this climate mitigation action and no summary information is available on the 2015 to 2020 RDPs.

Where it is appropriate to promote the use of feed additives, the relevant RDP measures could include:

- demonstration activities and information (M 1.2)

References

Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu, J.L., Lasorella, M.V., and Longhitano, D. (2014) "Mainstreaming climate change into rural development policy post 2013." Final report. Ecologic Institute, Berlin.

Moran, D., MacLeod, M., Wall. E., Eory, V., Pajot, G., Matthews, R, McVittie, A., Barnes, A., Rees, B, Moxey, A, Williams, A, and Smith, P (2008) UK Marginal Abatement Cost Curves for the Agriculture and Land Use, Land-Use Change and Forestry Sectors out to 2022, with Qualitative Analysis of Options to 2050. Final Report to the Committee on Climate Change, 20/11/2008, 152 pp.

Optimised feeding strategies for livestock

Description

This mitigation action aims to optimize dietary intake by matching feed intake to the requirements of the animals. Farm animals are often fed diets with more crude protein than they need, to safeguard against a loss of production from a protein deficit through inaccurate analysis and/or formulation of the diet. Surplus N is not utilized by the animal and is excreted. The main source of dietary N use inefficiency, for the dairy cow at least, is the rumen (Moorby *et al.,* 2007). Restricting diets to only the required amounts of N can limit the amounts excreted without affecting animal performance. Excretion can also be reduced by changing the composition of the diet to increase the proportion of dietary N utilised by the animal; for example, by optimizing the balance of N to carbohydrate in ruminant diets or by reducing the proportion of rumen-degradable protein (Moorby *et al.,* 2007). This requires better characterisation of animal diets (e.g. conserved forages) to allow any supplementary feeds (concentrates or straight mix feeds) to be chosen (Moorby *et al.,* 2007).

Mode of action

A diet closely matched with the animal's requirements improves general health and fertility, improving production at the herd level (Frelih-Larsen *et al.,* 2014). Enteric CH_4 emission per unit of product may also be reduced through maintaining a healthy rumen and maximizing microbial protein synthesis. The main GHG reductions are achieved through reductions in direct and indirect N_2O emissions from excreta and manure as a result of reducing N excretion.

Reduction in N excretion is achieved by adjusting protein content to match animal requirements. This often involves supplementing diet with synthetic essential amino acids.

Mitigation potential

Influencing factors

The GHG mitigation potential is uncertain as it will depend upon current feeding practice. Many EU farmers are already using best practice but there is likely to be potential to improve diets in newer MSs and in regions where livestock are raised extensively.

Table 37: Summary of influencing factors for optimised feeding strategies for livestock

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Livestock
Which soil types is this MA relevant to?	N/A
Which climatic zones is this MA relevant to?	N/A

Values

Frelih-Larsen *et al.,* (2014) cite reductions of 5 to 60%, 10 to 35% and 25 to 50% reduction in N excretion for pigs, poultry and cattle, respectively.

Although this mitigation action has the potential for reducing emissions of CH_4 as well as N_2O the greatest proven reductions are in emissions of N_2O from better matching of feed protein concentrations to livestock requirements. For that reason, we have limited the assessment of abatement potential to the reduction of N_2O emissions from excreta and manure deposited to land. The GHG mitigation potential is very uncertain as it will depend upon current feeding practice. For example for cattle farms that are using total mixed rations with a balance among maize silage, grass silage and cereal-based concentrates there will be less potential to reduce protein intake further compared with cattle farms where the bulk of the feed is grass. Hence the wide range of abatement potentials. The values presented were derived from an evaluation of the information reviewed.

The reported reductions in N excretion arising from this MA reported by Frelih-Larsen *et al.,* (2014). We have made a very conservative interpretation of those values for two reasons. First, for pigs and poultry, phase feeding and the use of synthetic amino acids have been widely adopted by producers and future reductions in N excretion are likely to be at the lower end of the ranges cited (5 and 10% for pigs and poultry respectively). Second, for cattle, due to the implications for GHG emissions from ploughing out grassland to grow maize and cereals it is likely that, without land use change, there will be limited options to replace grass-based forages with high energy feeds.

We used a range of 2.5 to 7.5% of baseline emissions, where the baseline is the N_2O emissions from manure management in the 2012 national inventory reports (2014 submission).

The mitigation potential at Member State level (kt CO_2e/y) is shown in Figure 43. The mitigation potential per head of livestock by Member State is shown in Figure 44.

Figure 43: Mitigation potential at Member State level, kt CO_2e/y

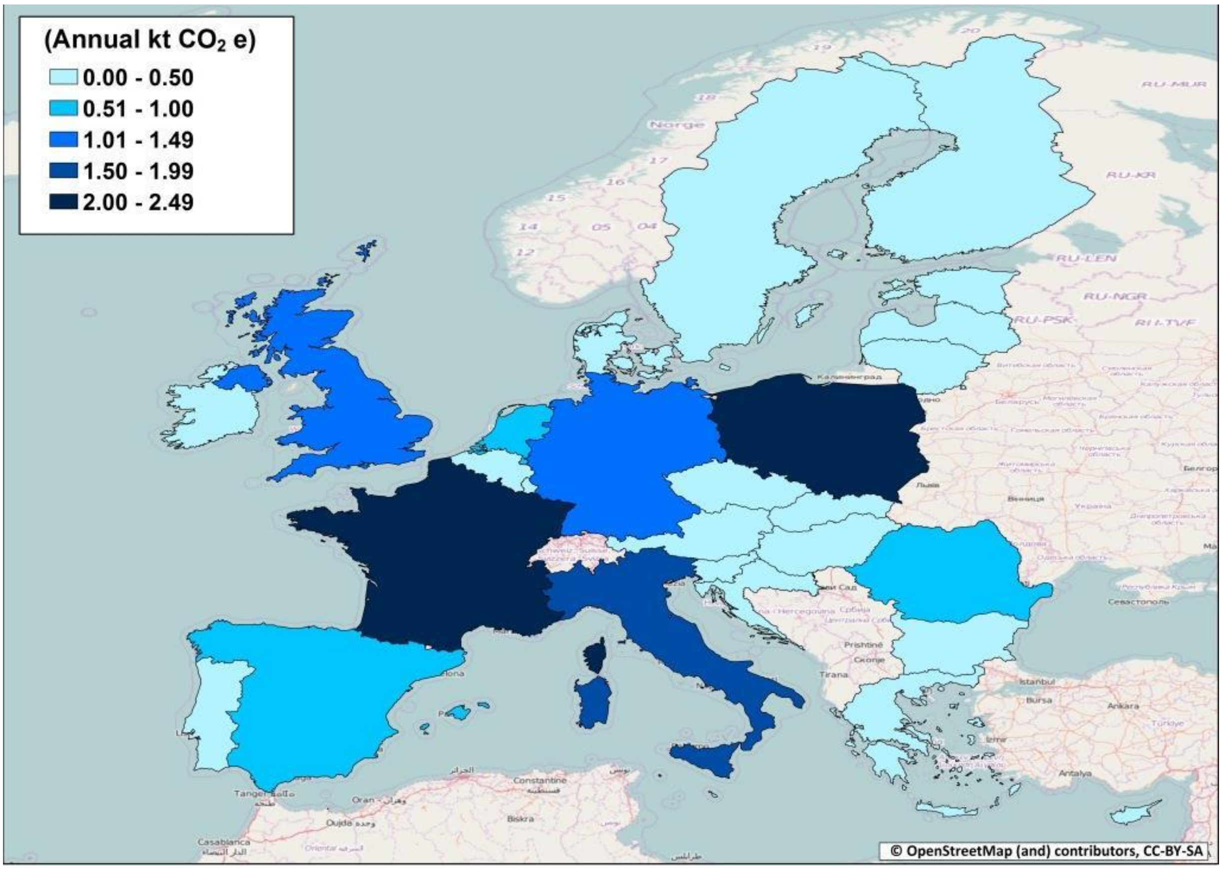
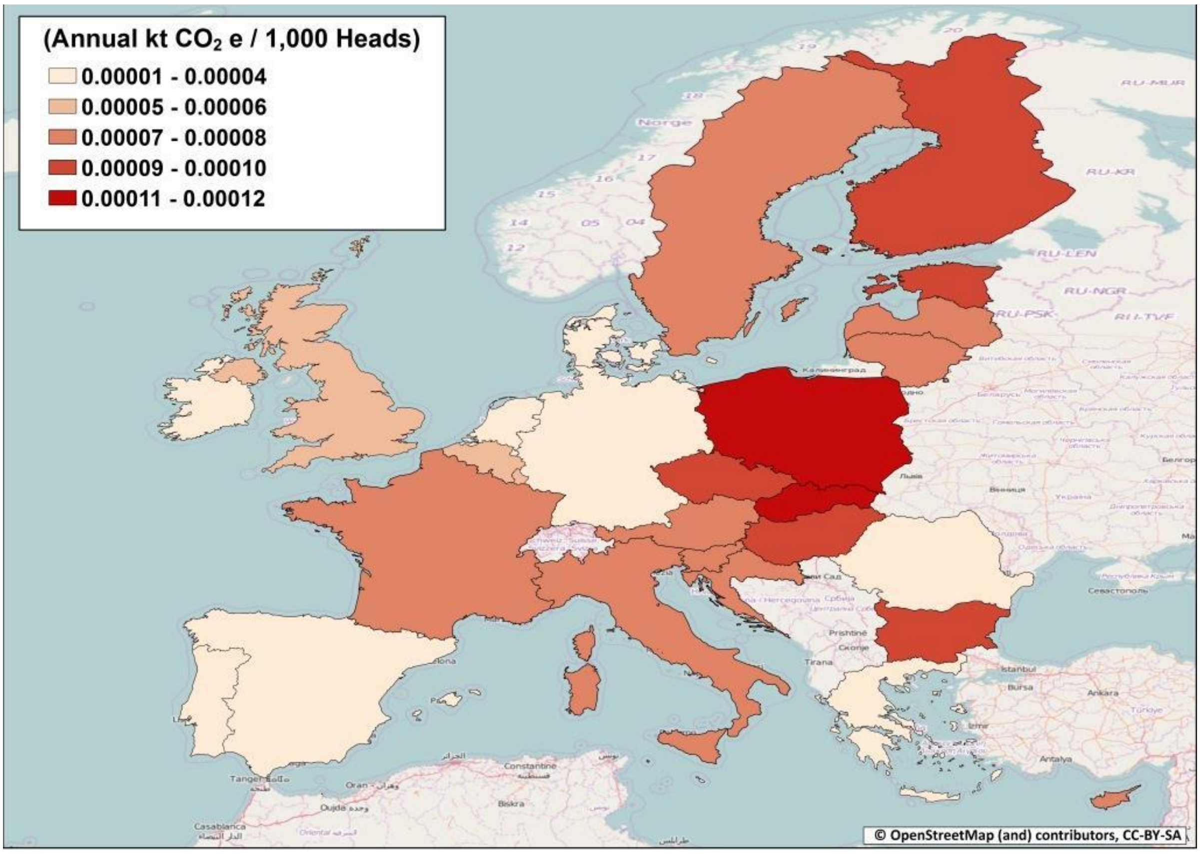


Figure 44: Mitigation potential per 1000 head of livestock (cattle only) by Member State.



Environmental co-benefits and risks of the MA

There are other environmental benefits of this action, additional to the effect on GHG emissions, which are a consequence of reduced N excretion by livestock as a result of matching protein intake to requirements. These benefits could include:

- reduced ammonia emissions;
- reduced nitrate leaching from manure and excreta, with consequent benefits for water quality.

There are unlikely to be any risks to the environment from implementing this action.

Technological and socio-cultural barriers

Nutritional recommendations for different types of livestock are widely available, but the availability of feedstuff needed for precise feed formulation might vary among countries and this could limit the potential uptake in parts of the EU. Some feedstuffs are not suitable for organic farms (e.g. synthetic essential amino acids).

Costs/business benefits to land managers of implementing the MA at farm/forest level

The costs will vary from farm to farm, depending on the current composition of livestock diets, the type and extent of the changes needed and the cost and availability of the feedstuffs to achieve these.

Farmers could choose to implement this climate mitigation action in the short-term (before 2020), but individual decisions will be influenced by the economic impact on the farm business and possibly other factors, such as availability of feedstuffs.

Geographic relevance

The potential for optimised feeding strategies is related to livestock density. Livestock density by Member State is shown in Figure 45. Livestock density by NUTS 2 level is shown in Figure 46.

Figure 45: Livestock density by Member State

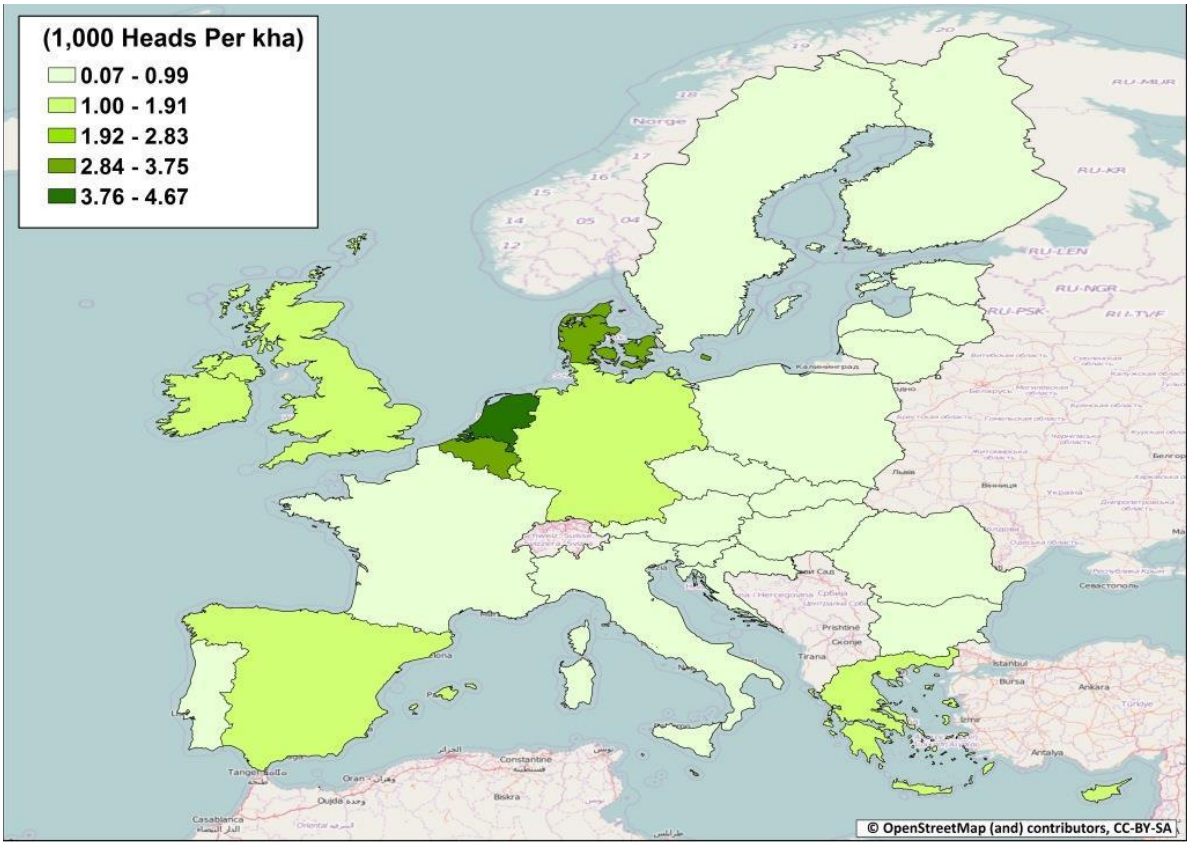
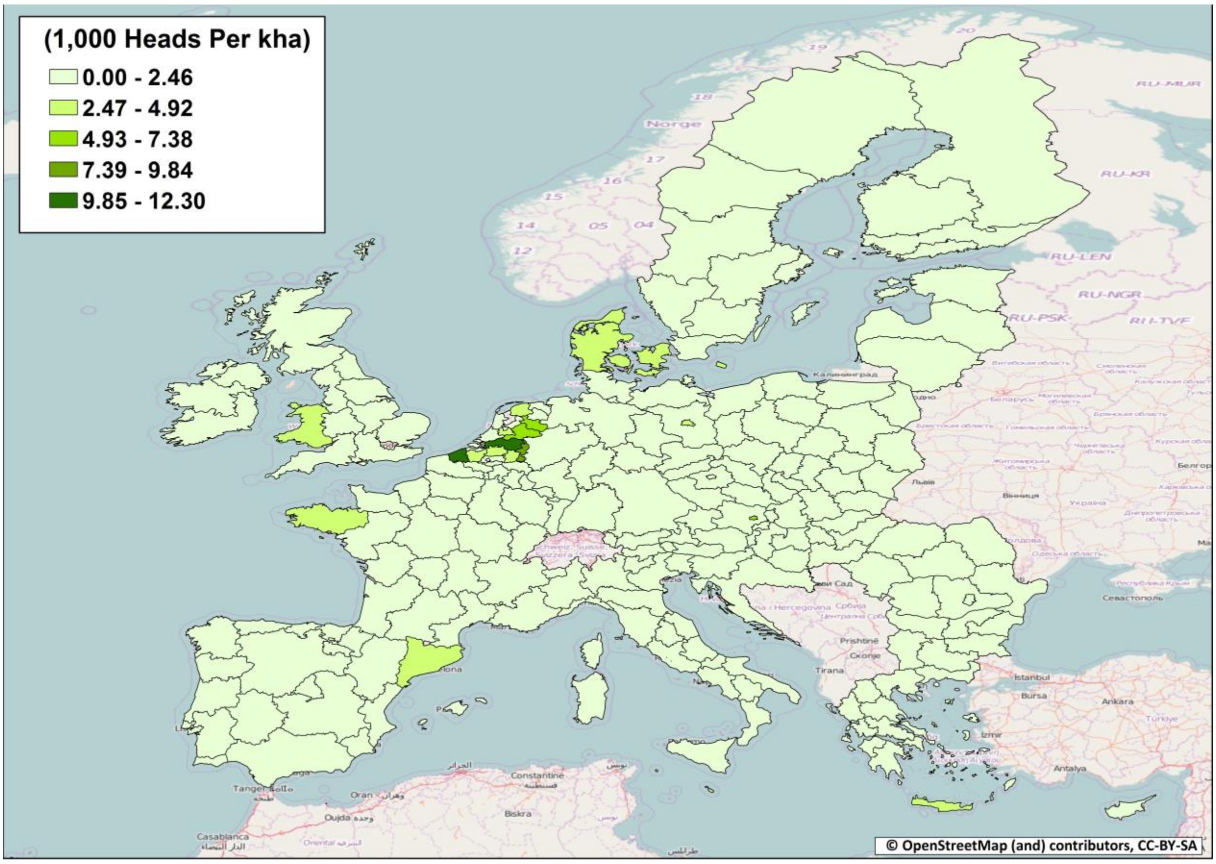


Figure 46: Livestock density by NUTS 2 level



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 38.

Table 38: Summary of reporting issues for optimised feeding strategies for livestock

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes, This is based on the ability to collect appropriate activity data and Emissions Factors which will be complex are require a tier 3 methodology. Activity Data will also be challenging to collect and require differentiation on specific feed strategies.
Is there a methodology that will show specific impact of the mitigation action? What is it?	There are No detailed methods detailed within he NIRs reviewed that would allow for reporting on different feed strategies. We believe that an appropriate method could be developed under tier 3.
Categories	Enteric Fermentation

Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Enteric Fermentation
Which Member States included this as a Key Category in their 2014 National Inventory Reports	23 member states record Enteric Fermentation as a Key Category. AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,FR,HR,IT,LT,LU,LV,NL, PL,PT,SE,SI,SK,UK
Tiers used	Tier 1: 3 MSs ES,HU,MT Tier 2: 23 MSs AT,BE,BG,CY,CZ,DK,EE,EL,FI,FR,HR,IE,IT,LT,LU,LV,PL,PT, RO,SE,SI,SK,UK Tier 3: 2 MSs DE,NL Not Assessed: 0 MS The tier used in some cases changes according to the species. Many member states use tier 2 approach to calculate emissions from cattle with tier 1 approach for sheep for example.
Limitations of the Inventory reporting structure	Relies on accurate emissions factors for animals fed on different diets and the ability to capture Activity Data relating to dietary variation. Explicitly says that there is considerable room for improvement within the guidance.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

The measure level reports and analyses of the 2007 to 2013 RDPs are too broad brush to permit identification of this climate mitigation action and no summary information is available on the 2015 to 2020 RDPs.

EIP Agri recently set up a Focus Group to consider how to reduce cattle livestock emissions in a way that is cost effective for farmers. The topics to be considered include, for example, 'competitive farm management practices and strategies related to housing and feeding which are currently available'[29].

Where it is appropriate to promote this action, the relevant CAP measures could include:

- demonstration activities and information (M 1.2)
- setting up farm and forestry advisory services (M 2.2) to provide through the Member State's Farm Advisory Service information on: GHG emissions of the relevant farming practices; on the contribution of the agricultural sector to mitigation through improved

[29] http://ec.europa.eu/eip/agriculture/en/content/reducing-emissions-cattle-farming

farming and agroforestry practices; and on how to improve and optimise soil carbon levels[30];

- possibly EIP operational groups and pilot projects (M 16.2).

References

Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu, J.L., Lasorella, M.V., and Longhitano, D. (2014). "Mainstreaming climate change into rural development policy post 2013." Final report. Ecologic Institute, Berlin.

Moorby, J.M., Chadwick, D.R., Scholefield, D., Chambers, B.J., and Williams, J.R. (2007). A Review of Research to Identify Best Practice for Reducing Greenhouse Gases from Agriculture and Land Management. Final report of Defra project AC0207, October 2007, 74pp.

[30] This information is an option for Member States, not a required part of the Farm Advisory Service. Article 12.3 and Annex 1 of Regulation (EU) 1306/2013

Soil and nutrient management plans

Description

A Soil Management Plan identifies inherent and management risks for soil erosion by wind or water at a farm / field scale. A plan provides a structured framework to record and implement multiple techniques which are cost effective over a number of years. Actions should be reviewed and updated annually.

A nutrient budget is incorporated into a Nutrient Management Plan to help identify which management practices should be selected and implemented to improve nutrient efficiency in the farm system. Using a nutrient budget can quantify the amount of nutrients being imported or exported to a system. This can be used at a farm, water catchment or country level. Leip *et al.,* (2011) describes types of nutrient budgets:

- Farm gate nutrient budget – is constructed in the boundaries of a farm and records the amounts of N in all kinds of products that enter and leave the farm gate which are imported and exported at a farm level. This is based on feed, fertilizer, crop, and animal products data, collected at the farm. Throughputs, for example the uptake of grass by animals, or the application of manure are not part of the farm N-budget. The surplus/deficit is a measure of total N losses, adjusted for possible changes in the storage of nutrients in the farm system.
- Soil surface nutrient budget – records all N that is added to the soil and that leaves the soil with harvested products or crop residues. N inputs via fertilizer and animal manure are adjusted for losses via ammonia volatilization from housing and manure management systems (as this is not applied to the soils). The surplus/deficit is a measure of the total N loss from the soil, adjusted for possible changes in the storage of nutrients in the soil. Some soil surface nutrient budgets also exclude volatilization that occurs during manure application.
- Gross Nutrient Budget (GNB), Eurostat (2013) - the GNB takes the extended soil surface as the system boundary and includes also the N losses from housing and manure management systems to obtain a proxy for the overall environmental pressure including the pollution of soil, water and air.

Mode of action

This mitigation action is considered with respect to its potential for reducing emissions of N_2O.

Soil and nutrient management plans do not directly reduce GHG emissions, but GHG abatement results from implementation of actions and recommendations identified in a management plan.

The use of soil management plans can identify areas where management practices could be improved or changed. Using best management practices leads to reduced residual soil NO_3^- and can decrease the risk of N_2O emissions. Improving soil structure for rooting potential can increase biomass production, which will increase or maintain soil carbon levels.

Mitigation potential

Influencing factors

The mitigation potential depends on the action(s) included in the plan, and the implementation of those actions.

Mitigation potential will vary between seasons depending on differences in weather and crop performance.

This mitigation action is effective across a wide range of soil types and farming systems, and so is effective across the EU.

Table 39: Summary of influencing factors for soil and nutrient management plans

Relevance to farming systems, soil types and climatic zones		
	Soil management plans	Nutrient management plans
Which farming sectors/systems is this MA relevant to?	All	All
Which soil types is this MA relevant to?	All	All
Which climatic zones is this MA relevant to?	All	All

Values

The potential for reduction in N_2O emissions from reductions in N fertilizer use was estimated. Such reductions would arise from a range of measures such as taking full account of residual mineral N in the soil from crop residues, manure applications and previous N fertilizer use and through differential N applications within fields to take account of spatial variation in soil mineral N. No explicit estimates of potential GHG emission reductions from the adoption of this mitigation action were found in the literature, but the ranges below were derived by analogy with the potential abatement reduction considered feasible from improved N efficiency.

We used a range of 2.0 to 5.0% of baseline emissions, where the baseline is N_2O emissions from managed soils in the 2012 national inventory reports (2014 submission).

The mitigation potential at Member state level for CO_2e/y and $CO_2e/y/ha$ is shown in Figure 47 and Figure 48 respectively.

Figure 47: Mitigation potential at Member State level, kt CO_2e/y

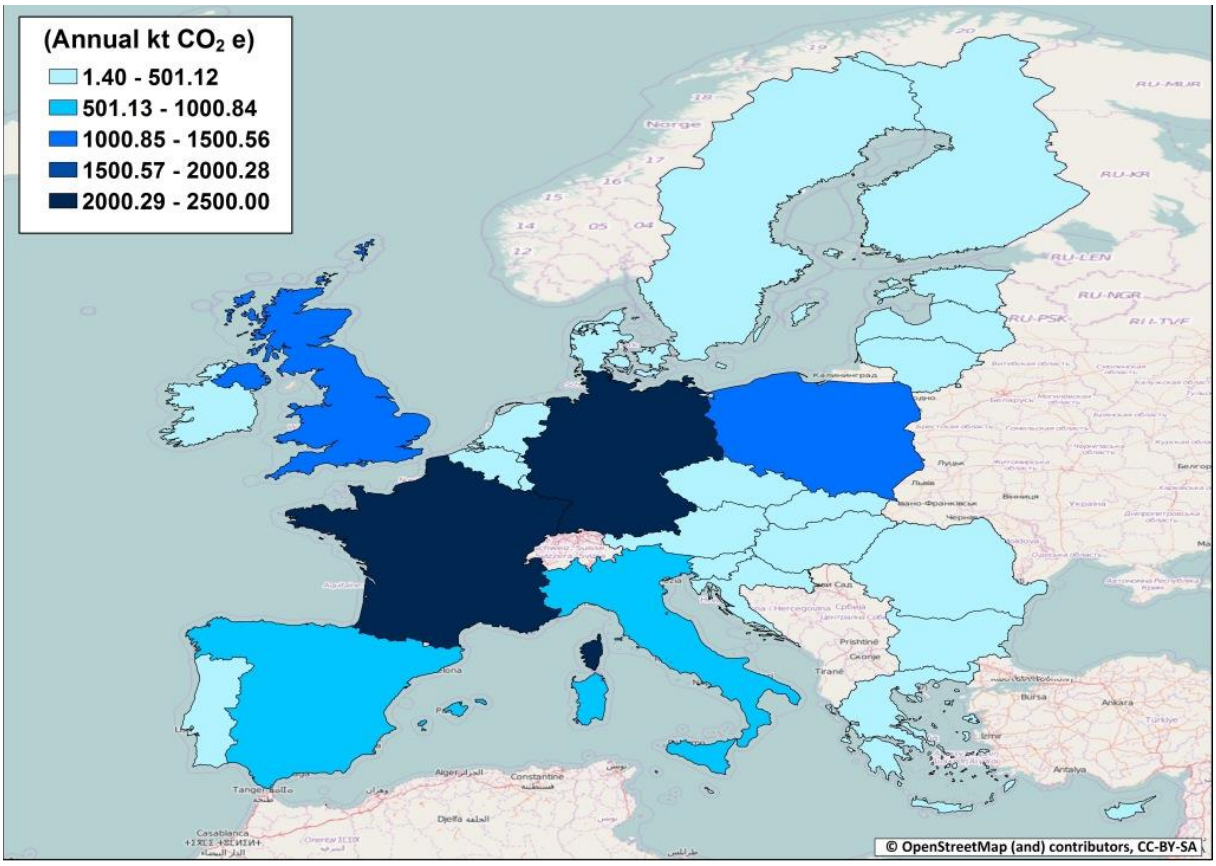
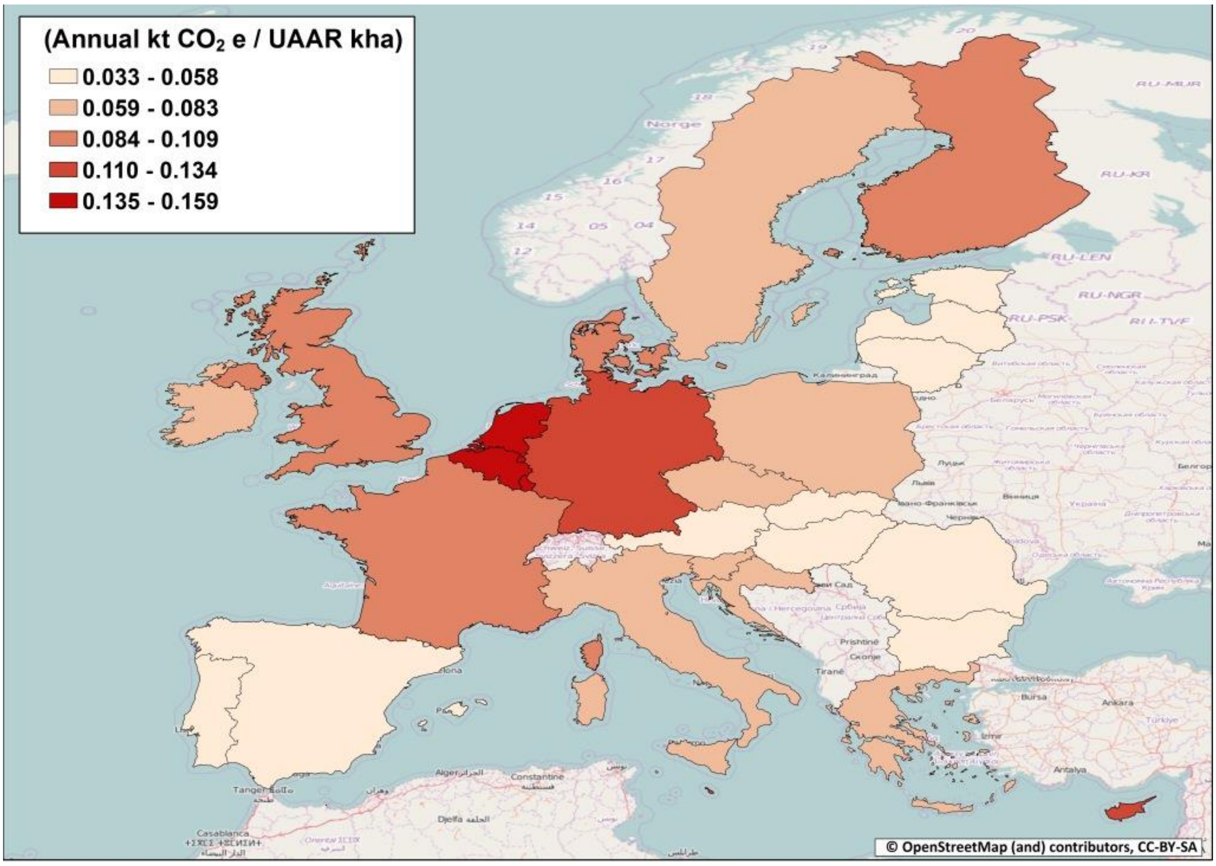


Figure 48: Mitigation potential per hectare at Member State level, kt CO_2e/kha/y



Environmental co-benefits and risks of the MA

There are other environmental benefits of this action, additional to the effect on GHG emissions, but these depend not the preparation of the plans but on the effect of the subsequent actions taken to implement the plans. Benefits may include:

- reduced diffuse pollution from N fertilizers and manure/slurry;
- less risk of soil erosion; and
- benefits for soil biodiversity.

No risks to the environment have been identified for the preparation or implementation of the plans.

Technological and socio-cultural barriers

The techniques of soil and nutrient planning are well understood by the scientific and advisory community but uptake among farmers is not known and may be lower among smaller or economically marginal livestock farms.

Costs/business benefits to land managers of implementing the MA at farm/forest level

The preparation of soil and nutrient management plans incurs additional costs of management time, and for nutrient management plans technical advisory input and possibly soil analysis may also be required. Implementation of the plans may lead to savings in fertilizer costs (through using nutrients more efficiently) and possibly longer-term gains in soil quality.

Farmers could choose to implement this climate mitigation action in the short-term (before 2020), but individual decisions will be influenced by the economic impact on the farm business and possibly other factors.

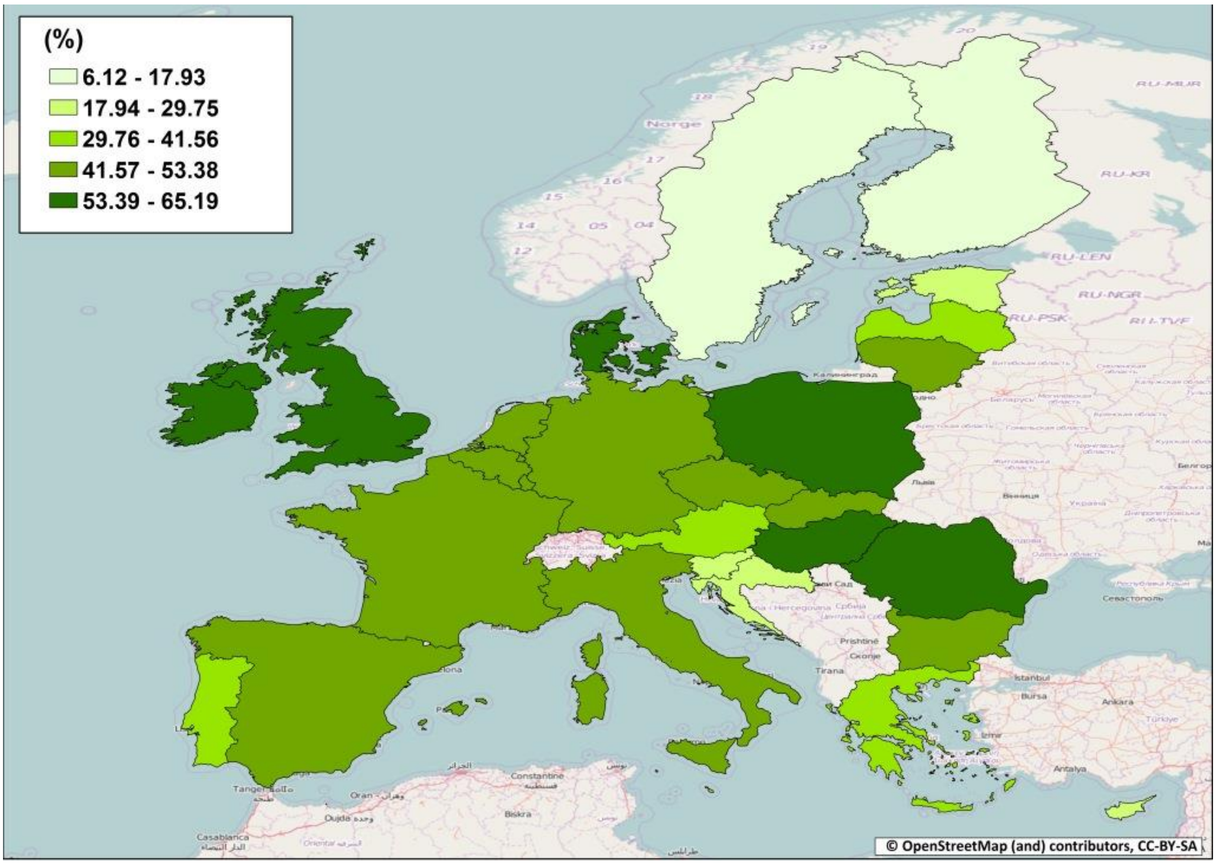
Geographic relevance

Soil and nutrient management plans can be used on all agricultural land. In Figure 49, the land currently in agricultural production is shown as the percentage of total land area, by Member State.

In NVZs, soils and nutrients are well managed, but there may be some (small) scope for further improvement. On land that is non-NVZ and non-LFA, we would expect greater scope for improvement because current uptake is judged to be lower than in NVZs, and N is usually applied. In LFAs, we expect a lower level of improvement because there is less application of N (often little or no inorganic N is applied and much of the grassland is grazed with little spreading of manure from housed livestock).

Alongside the uptake factor we have an abatement potential range that is very wide (1% to 10% of N_2O emissions from managed soils) reflecting small abatement potential in NVZs and larger potential in non-NVZs.

Figure 49: Utilisable agricultural area as a percentage of total area for each Member State



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 40.

Table 40: Summary of reporting issues for soil and nutrient management plans

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	No There is no direct mitigation because this action is a means of identifying further actions that will result in a GHG reduction.
Is there a methodology that will show specific impact of the mitigation action? What is it?	No
Categories	None

Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	None
Which Member States included this as a Key Category in their 2014 National Inventory Reports	Not applicable
Tiers used	Not applicable
Limitations of the Inventory reporting structure	Not applicable

Policy measures that could be or have been used to encourage implementation of the MA in the EU

LIFE projects have included the development of decision support tools for farmers including a real-time system that calculates nitrogen fertilizer requirements (the OptiMa-N project, LIFE04 ENV/IT/000454) and tools to optimise fertilisation and soil organic matter management (the DEMETER project, LIFE10 ENV/ BE/000699 (European Commission, 2014).

The measure level reports and analyses of the 2007-13 RDPs are too broad brush to permit identification of support for soil and nutrient management planning, and no summary information is available on the 2015-2020 RDPs. One study found that some of the 2007-13 agri-environment schemes required farm-level input from specialist advisers on preparing nutrient management plans or assessing soil erosion risks (Keenleyside, 2011). An example of RDP funding for nutrient management planning is described in Box 3. Also, it is possible that Member States will have promoted soil and nutrient management planning through RDP funded advisory services. For example, the Lower-Saxony RDP used the advisory services measure (114) to pay farmers 80% of the advisory costs in the fields of water protection, biodiversity and climate protection, although nutrient management planning is not specifically mentioned (ENRD, 2012).

Box 3 Nutrient management planning and advice in Finland and Sweden (2007-13 RDPs)

In **Finland** improving water protection is a central element of the Finnish agri-environment programme and requirements for planning, monitoring and fertilizer use are mandatory for every beneficiary. The objective is to increase the accuracy in fertilizer application in different parcels through regular soil mapping and analysis (every five years), annual cultivation plans prepared by farmers and annual recording of basic data, together with the specific farming practices carried out (including sowing). This parcel-based planning and monitoring approach allows farmers to take into account the specific farm and parcel needs when establishing environmental management measures both annually and across several years. This approach has been in operation since 2000 and the continuity provided over successive RDPs has led to increased confidence and awareness of farmers, allows for longer term planning and it provides a contribution towards consistent environmental goals (ENRD, 2013).

In **Sweden** Focus on Nutrients is an advisory service, partly financed by both national and EU funds, which adopts innovative training and advisory approaches and has become a well-established concept among the farming community, with more than 8,000 members in 2011. The advice programme is voluntary, free of charge and individually tailored to farms that have more than 50 hectares of land or 25 livestock units. The programme involves a start-up visit by qualified advisors to identify particular practices to be adopted by the farmer. Between the beginning of the project in 2001 and 2011, a total of 40,000 farm visits were carried out by 250 advisers as part of the effort to reduce nutrient losses. Nine out of ten farmers implement the measures proposed. Results show that farms became more resource efficient, decreasing nitrogen and phosphorus leaching by 800 and 30 tonnes per year respectively (Greppa Näringen, 2011).

Relevant CAP measures to promote the preparation and implementation of soil and nutrient management plans include:

- possibly GAEC 5 minimum land management to limit soil erosion
- possibly GAEC 6 maintenance of soil organic matter
- demonstration activities and information actions (M 1.2)
- setting up farm and forestry advisory services (M 2.2) to provide through the Member State's Farm Advisory Service information on: GHG emissions of the relevant farming practices; on the contribution of the agricultural sector to mitigation through improved farming and agroforestry practices; and on how to improve and optimise soil carbon levels[31]
- agri-environment-climate payments (M10.1)

References

ENRD (2013) Rural Review No.15 http://enrd.ec.europa.eu/enrd-static/fms/pdf/21B49934-A7DE-CAAC-FCF4-F4A4E92B24A9.pdf

ENRD (2012) Final Report of the Focus Group on the Delivery of Environmental Services http://enrd.ec.europa.eu/enrd-static/fms/pdf/A5BC1168-C8C5-6EB2-EA66-720D64516F54.pdf

Eurostat (2013) *Nutrient Budgets, EU-27, NO, CH. Methodology and Handbook. Version 1.02* (Luxemb: Eurostat and OECD Online: http://ec.europa.eu/eurostat/documents/2393397/2518760/Nutrient_Budgets_Handbook_%28CPSA_AE_109%29_corrected3.pdf/4a3647de-da73-4d23-b94b-e2b23844dc31

Greppa Näringen (2011) Focus on Nutrients 10 years – a decade of advice benefiting agriculture and the environment. Greppa Näringen, Elevenborgsvägen 4, SE-230 53 Alnarp, Sweden. http://www.greppa.nu/download/18.37e9ac46144f41921cd1d91e/1402565315382/A+decade+of+advice+-+Focus+on+nutrients.pdf

Leip A, Britz W, Weiss F and de Vries W (2011) Farm, land, and soil nitrogen budgets for agriculture in Europe calculated with CAPRI. *Environmental Pollution,* 159, 3243–53

Pronk,A.A, Bijttebier J., Ten Berge, H.,RuysschaertG., Hijbeek R., Rijk, B., Werner M., Raschke I., Steinmann, H.H., Zylowska, K.,Schlatter N., Guzmán G., Syp A., Bechini L., Turpin N., Guiffant N.,Perret, E., Mauhé, N., Toqué, C., Zavattaro L., Costamagna C., Grignani, C., Lehninen, T., Baumgarten, A.,Spiegel, H., Portero, A.,Van Walleghem, T.,Pedrera, A., Laguna, A., Vanderlinden, K.,Giráldez, V., Verhagen A. (2015) Compatibility of Agricultural

[31] This information is an option for Member States, not a required part of the Farm Advisory Service. Article 12.3 and Annex 1 of Regulation (EU) 1306/2013

Management Practices and Types of Farming in the EU to enhance ClimateChange Mitigation and Soil Health List of Drivers and Barriers governing Soil Management by Farmers, including CostAspects Catch-C project Deliverable 4.434 http://www.catch-c.eu/deliverables/D4.434_List_Drivers_Barriers.pdf

Use of nitrification inhibitors

Description

Nitrification inhibitors (NI) are compounds that slow down (inhibit) the conversion (nitrification) of ammonium ions (NH_4^+) to NO_3^-. Inhibitors can potentially be applied, as part of mineral N fertilizer formulations, to manures in storage and when spread to land, be sprayed on grazed land periodically at critical times of enhanced nitrification, or be dosed to animals via slow release boluses.

Nitrification inhibitors may be applied at the same time as fertilizer / manure applications.

The rationale of using NIs is that the rate of nitrification is slowed so that NO_3^- is formed at a rate that the crop can use, increasing N efficiency and reducing environmental losses via N_2O emissions and NO_3^- leaching.

Mode of action

This mitigation action is considered with respect to its potential for reducing emissions of N_2O.

Nitrification inhibitors (NI) are compounds that slow down (inhibit) the conversion (nitrification) of ammonium ions (NH_4^+) to NO_3^-. Nitrification is a process that can produce the GHG N_2O as a by-product. The NO_3^- produced by nitrification can also be denitrified in soils and be a further source of N_2O emissions.

Compounds such as nitrapyrin, dicyandiamide (DCD) and 3,4- dimethylpyrazole phosphate (DMPP) have been demonstrated to be effective in reducing N_2O emissions following the application of N fertilizer and livestock manures. DCD has been evaluated for reducing N losses from autumn-applied slurries for many years, but has generally failed to gain acceptance with the farming community due to not being cost-effective in terms of giving yield benefits (Schulte and Donnellan, 2012; Adler *et al.,* 2013). However, Dittert *et al.,* (2001) showed that inhibitors reduced N_2O emissions by about 30% when they were mixed with slurry and injected into grassland in late summer. More recent research has shown that NIs can be extremely effective, when added to mineral fertilizer, manures and even dosed to animals, in reducing N_2O emissions; reducing by *c*. 70% under field conditions (Hatch *et al.,* 2005).

Mitigation potential

Influencing factors

There is likely to be some variation across the EU as the persistence of NIs in soil is reduced under warm and wet conditions.

The effectiveness of NI (specifically DCD) depends largely on temperature, moisture, and soil type. For example, the longevity of DCD decreases with increasing soil temperature (de Klein and Monaghan, 2011).

Table 41: Summary of influencing factors for use of nitrification inhibitors

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Any system with crops that have applications of N. This includes many annual and perennial crops, including forage crops and grass.
Which soil types is this MA relevant to?	Any.
Which climatic zones is this MA relevant to?	Any.

Values

Estimates vary. For example, Misselbrook *et al.,* (2014) concluded that DCD could reduce N_2O emissions from UK agriculture by 20%. They cited an abatement estimate of 50% for New Zealand.

Moorby *et al.,* (2007) reviewed the available literature on the impacts of NI on GHG emissions. They reported that N_2O emissions may be reduced by 30% when an inhibitor is mixed with slurry which is then injected into grassland.

Zaman *et al.,* (2008) reported that NI reduced N_2O emissions following application of urea by 38%.

Eckard *et al.,* (2010) in a review of GHG mitigation options from livestock production reported abatement of up to 80% of N_2O emissions. However, the authors considered that many of the studies reviewed had been conducted under optimal conditions for N_2O production and over short periods, so the potential on-farm abatement is likely to be more conservative than the published data.

Dalgaard *et al.,* (2011) used an abatement factor of 60% of N_2O emissions arising from the NH_4 component of mineral fertilizers from the use of NIs in their estimation of potential GHG mitigation by agriculture in Denmark.

Luo *et al.,* (2013) reported a 20% reduction in N_2O emissions over three years from a grazed pasture.

Misselbrook *et al.,* (2014) found that DCD proved to be very effective in reducing direct N_2O emissions following fertilizer and cattle urine applications under UK conditions, with mean reduction efficiencies of 39, 69 and 70% for ammonium nitrate, urea and cattle urine, respectively. They concluded that the use of DCD could give up to 20% reduction in N_2O emissions from UK agriculture, but cost-effective delivery mechanisms are required to encourage adoption by the sector.

Luo *et al.,* (2008) reported up to 45% reduction in N_2O emissions from dairy cow urine following the application of DCD to various soils in New Zealand and pointed out that the effectiveness of these compounds may be reduced under heavy rainfall. More recent national trials in New Zealand reported an average N_2O reduction by DCD of 50% (Gillingham *et al.,* 2012).

Beukes *et al.,* (2010a) found that production fell by 1% with the use of NI, although N_2O emissions were reduced by *c*. 6%. Nevertheless, Beukes *et al.,* (2010b; cited in Doole, 2014) identified NI as a cost-effective means of reducing N_2O emissions on the basis that emissions were reduced by an average of 30%.

We used a range of mitigation potential values based on the average abatement reported by Misselbrook *et al.,* (2014) for the reduction in N_2O emissions measured under UK conditions when nitrification inhibitors were added to N fertilizers. The reductions reported in this paper are within the range reported in other studies. The average reported was a 39% reduction in N_2O emissions from ammonium nitrate (AN) and 69% reduction from urea. We took the mean value as 45%, since AN is more commonly used than urea and we considered the upper and lower values could reasonably be ±50% of this value.

In summary, we used a range of 22.5 to 67.5% of baseline emissions, where the baseline is the total of direct and indirect soil emissions of N_2O in the 2012 national inventory reports (2014 submission).

The mitigation potential at Member State level, CO_2e/y is shown in Figure 50. The mitigation potential at Member State level, CO_2e/y/ha is shown in Figure 51.

Figure 50: Mitigation potential at Member State level, kt CO_2e/y

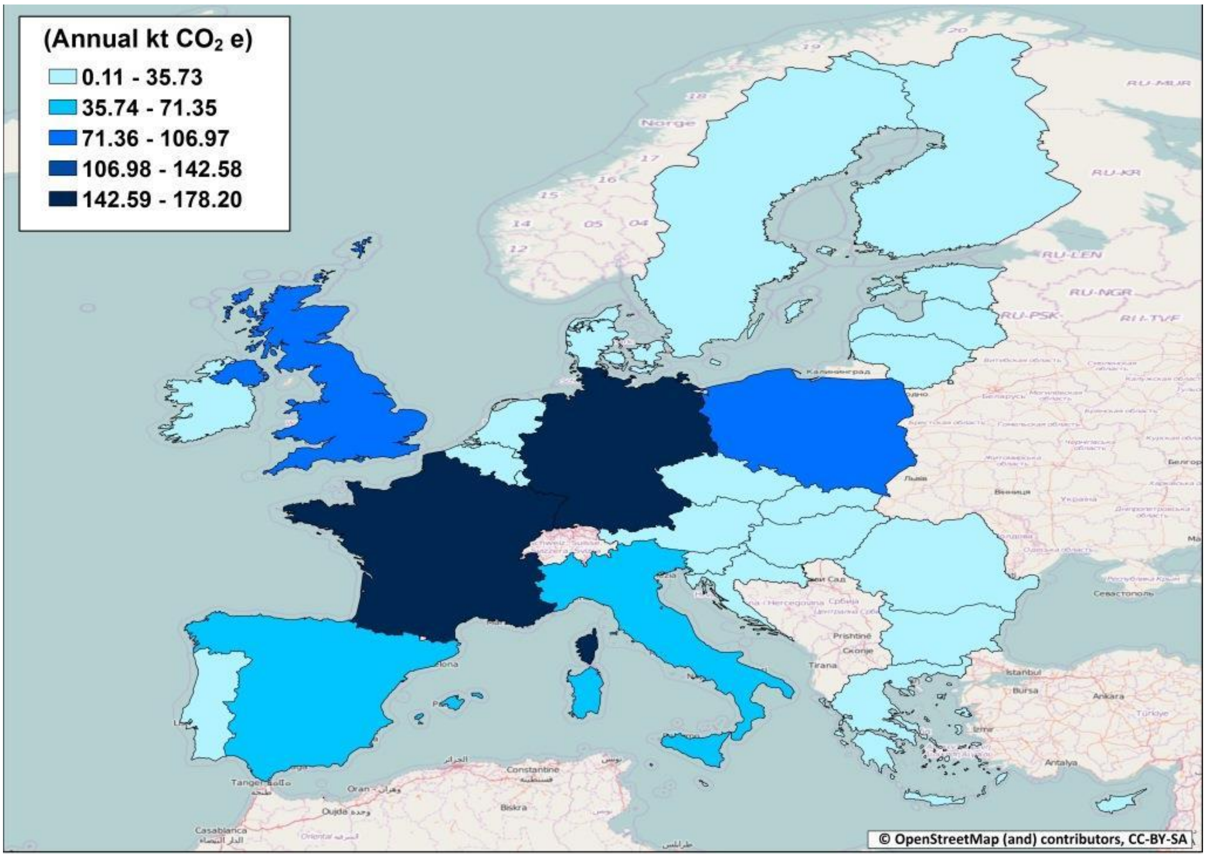
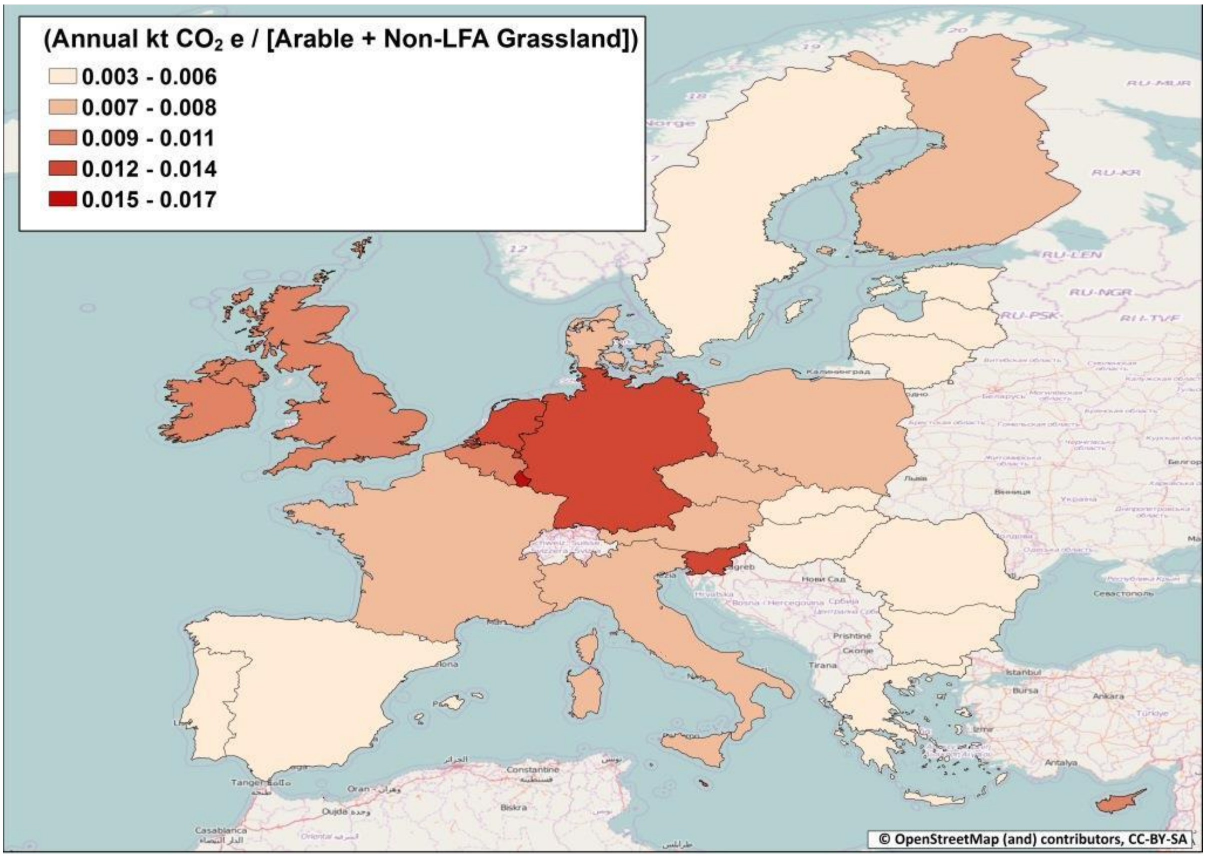


Figure 51: Mitigation potential at Member State level, kt CO_2e/kha/y



Environmental co-benefits and risks of the MA

The main additional environmental benefit of this action is the impact on nitrate leaching, with studies showing reductions of between 35% (Moorby *et al.,* 2007) and 70% (Di and Cameron, 2002, 2005) with consequent benefits for:

- reduced nitrate pollution of water courses.

The research reviewed does indicate any significant risks to the environment from correct use of nitrification inhibitors applied with manures and fertilizers, but there has been no experience of widespread use on EU farms.

Technological and socio-cultural barriers

There should be no technological problems in the use of NI-enhanced nitrogen fertilizers but good practice will need to be followed when NIs are applied with livestock manures, to achieve the mitigation effect.

In New Zealand residues of DCD were found in milk after cattle had been dosed with this NI, which was then voluntarily withdrawn from use. Although there is no risk to human health (this is reported to have been confirmed by the Official Institute for Public Health of the Federal Republic of Germany (Trenkel, 2010)) the concern in New Zealand was that the presence in milk of even small amounts of residues for which there is no international standard might be a barrier to trade.

Costs/business benefits to land managers of implementing the MA at farm/forest level

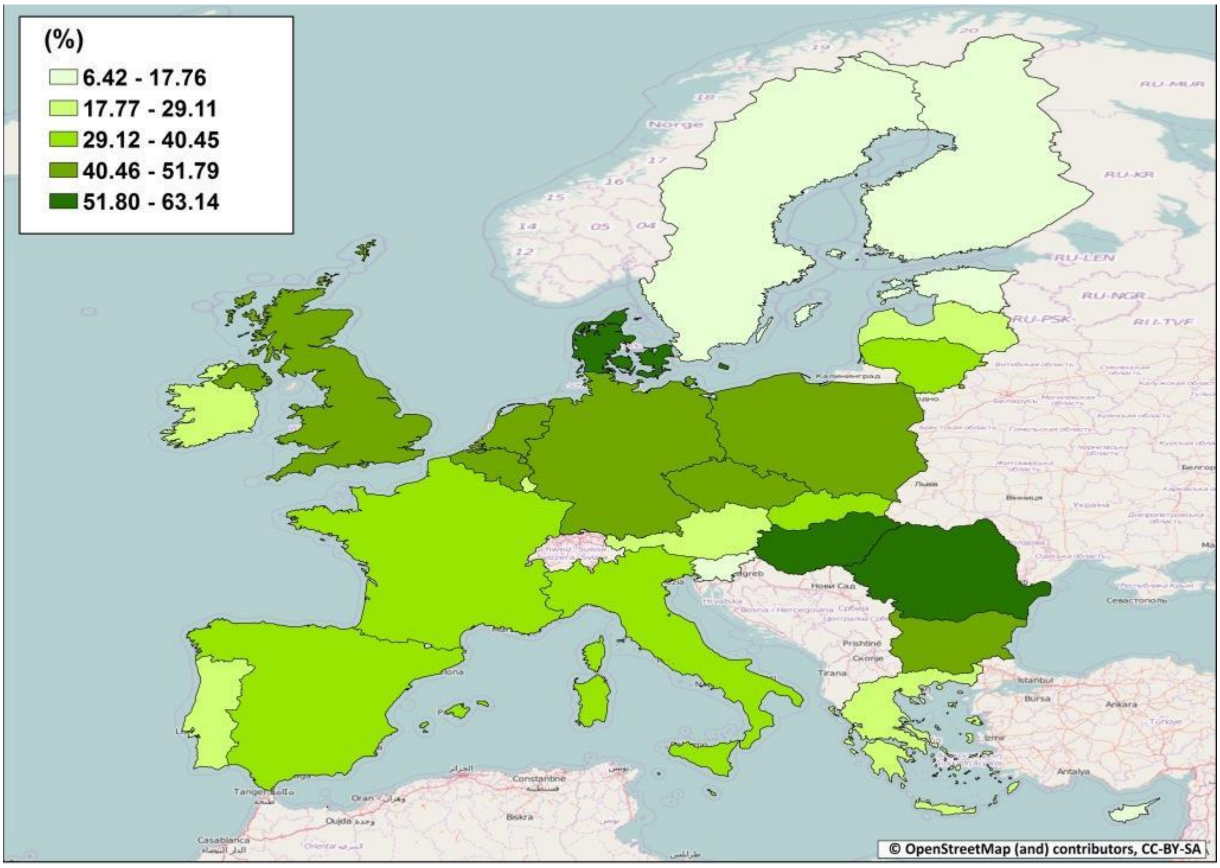
Nitrification inhibitors are expensive, do not improve crop yields (Misselbrook *et al.,* 2014), and may decrease them (Beukes *et al.,* 2010a, 2010b. Studies in Ireland and New Zealand concluded that this is not a cost-effective management action for farmers, with an estimated cost in New Zealand of €125 per hectare (Adler *et al.,* 2013).

In view of the economic impact on the farm business it is difficult to see why any EU farmers would choose to use nitrification inhibitors, but if they did so this climate mitigation action could be implemented in the short-term (before 2020).

Geographic relevance

The applicability of nitrification inhibitors is related to area of arable and grassland (excluding LFAs). The area of arable and grassland (non-LFA) is shown in Figure 52.

Figure 52: Land in arable or grassland production (excluding LFAs) as a percentage of total area for each Member State



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 42.

Table 42: Summary of reporting issues for use of nitrification inhibitors

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	No Nitrous oxide (N_2O) emissions occur as a consequence of applying plant-available N to crops. Using additives such as inhibitors may not change the total amount of N applied, and effects on N_2O emissions are highly uncertain.
Is there a methodology that will show specific impact of the mitigation action? What is it?	No
Categories	Direct N_2O emissions from managed soils Indirect N_2O emissions from managed soils

Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Agricultural soils
Which Member States included this as a Key Category in their 2014 National Inventory Reports	26 MSs: AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,FR,HR,IE,IT,LT,LU,LV,MT,NL, PL,PT,RO,SE,SI,SK,UK
Tiers used	Tier 1: 23 MSs AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,HR,IT,LT,LU,LV,MT,PL, PT,RO,SE,SI,SK,UK Tier 2: 5 MSs ES,FR,HU,IE,NL Tier 3: 0 MSs Not specified: 0 MSs
Limitations of the Inventory reporting structure	Emissions of N_2O are highly variable, both temporally and spatially, so they are difficult to estimate or model, and it is not practical to measure emissions except in limited experimental areas. The Tier 1 and 2 methods use emission factors related to the quantity of N applied, so do not account for variation in time of application, type of fertilizer of other material containing N, or other efficiency measures that do not change the quantity of N applied.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

No examples were found of the use of EU funding to promote the use of nitrification inhibitors.

Where it is appropriate to promote this action, the most relevant CAP measure would be:

- agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) provided the requirements of verification and payment control of RDP payments can be met.

References

Adler, A., Doole, G.J., Romera, A.J., and Beukes, P.C. (2013). Cost-effective mitigation of greenhouse gas emissions from different dairy systems in the Waikato region of New Zealand, *Journal of Environmental Management,* 131, 33-43.

Beukes, P.C., Gregorini, P., and Romera, A.J. (2010a), 'Improving production efficiency as a strategy to mitigate greenhouse gas emissions on pastoral dairy farms in New Zealand', *Agriculture, Ecosystems and Environment,* 136, pp. 358–365.

Beukes, P.C., Gregorini, P., and Romera, A.J. (2010b), 'Estimating greenhouse gas emissions from New Zealand dairy systems using a mechanistic whole farm model and inventory methodology', *Animal Feed Science and Technology,* 166, pp. 708–720.

Dalgaard, T., Olesen, J.E., Petersen, S.O., Petersen, B.M., Jørgensen, U., Kristensen, T., Hutchings, N.J., Gyldenkærne, S. and Hermansen, J.E. (2011). Developments in greenhouse gas emissions and net energy use in Danish agriculture - How to achieve substantial CO_2 reductions? *Environmental Pollution,* 159, 3193-3203.

de Klein, C.A.M., and R.M. Monaghan. (2011) The effect of farm and catchment management on nitrogen transformations and N_2O losses from pastoral systems—Can we offset the effects of future intensification? *Current Opinions on Environmental Sustainability,* 3, 396–406.

Di, H.J., and Cameron, K.C. (2002) The use of a nitrification inhibitor, dicyandiamide (DCD), to decrease nitrate leaching and nitrous oxide emissions in a simulated grazed and irrigated grassland, *Soil Use and Management,* 18, 395–403.

Di, H.J., and Cameron, K.C. (2005) Reducing environmental impacts of agriculture by using a fine particle suspension nitrification inhibitor to decrease nitrate leaching from grazed pastures, *Agriculture Ecosystems and Environment*, 109, 202–212.

Dittert, K., R. Bol, R. King, D. Chadwick, and D. Hatch. (2001) Use of a novel nitrification inhibitor to reduce nitrous oxide emission from N-15- labelled dairy slurry injected into soil, *Rapid Communications in Mass Spectrometry*, 15, 1291-1296.

Doole G.J. Least-cost greenhouse gas mitigation on New Zealand dairy farms. (2014), *Nutrient Cycling in Agroecosystems,* 98, 235-251.

Eckard, R.J, Grainger, C., and de Klein, C.A.M. (2010) Options for the abatement of methane and nitrous oxide from ruminant production: A review, *Livestock Science,* 130, 47–56.

Hatch, D., Trindade, H., Cardenas, L., D., Carneiro, J., Hawkins, J., Scholefield, D. and Chadwick. D (2005) Laboratory study of the effects of two nitrification inhibitors on greenhouse gas emissions from a slurry-treated rable soil: impact of diurnal temperature cycle. *Biology and Fertility of Soils*, 41, 225–232.

Luo, J., Saggar, S., Bhandral, R., Bolan, N., Ledgard, S., Lindsey, S. and Sun, W (2008) Effects of irrigating dairy-grazed grassland with farm dairy effluent on nitrous oxide emissions, *Plant Soil,* 309, 119–130.

Luo, J, Ledgard, S.F. and Lindsey, S.B (2013) Nitrous oxide and greenhouse gas emissions from grazed pastures as affected by use of nitrification inhibitor and restricted grazing regime, *Science of the Total Environment,* 465, 107–114.

Misselbrook, T.H., Cardenas, L.M., Camp, V., Thorman, R.E., Williams, J.R., Rollett, A.J., and Chambers, B.J. (2014) An assessment of nitrification inhibitors to reduce nitrous oxide emissions from UK agriculture, *Environmental Research Letters,* 9, 1-11.

Moorby, J.M., Chadwick, D.R., Scholefield, D., Chambers, B.J. and Williams, J.R. (2007) A Review of Research to Identify Best Practice for Reducing Greenhouse Gases from Agriculture and Land Management. Defra Project AC0206, October 2007, 74 pp.

Schulte, R.P.O. and Donnellan, T. (eds.), (2012) A Marginal Cost Abatement Curve for Irish Agriculture. Teagasc submission to the public consultation on Climate Policy development. Teagasc, Carlow, 30 April 2012.http://www.teagasc.ie/publications/2012/1186/1186_Marginal_Abatement_Cost_Curve_for_Irish_Agriculture.pdf

Trenkel, M.E. (2010) Slow- and Controlled-Release and Stabilized Fertilizers: An Option for Enhancing Nutrient Efficiency in Agriculture. Second edition, IFA, Paris, France, October 2010, 160 pp.

Zaman, M., Nguyen, M.L., Blennerhassett, J.D., and Quin, B.F. (2008) Reducing NH_3, N_2O and NO_3-N losses from a pasture soil with urease or nitrification inhibitors and elemental S-amended nitrogenous fertilizers, *Biology and Fertility of Soils,* 44, 693-705.

Improved nitrogen efficiency

Description

This mitigation action is considered with respect to its potential for reducing emissions of N_2O.

For this candidate mitigation action we only consider management actions that aim to reduce the total application of N fertilizer by taking fully into account other sources of N available to the farm. Hence for this candidate mitigation action we are concerned primarily with making the best use of sources of N nutrition available on the farm with respect to both reducing the total amount of N fertilizer applied and using that N fertilizer most efficiently.

Elsewhere in this document we have evaluated mitigation actions which may also be considered to improve N efficiency.

Mode of action

By applying less N, as the total applied in fertilizer and other N sources, emissions of N_2O are decreased.

Mitigation potential

Influencing factors

Table 43: Summary of influencing factors for improved nitrogen efficiency

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Any system with crops that have applications of N. This includes many annual and perennial crops, including forage crops and grass.
Which soil types is this MA relevant to?	Any.
Which climatic zones is this MA relevant to?	Any.

Values

The estimates of potential abatement that we have used relate to the implementation of all the N efficiency measures discussed above. The wide range reflects the different potentials for increasing the efficiency of N fertilizer use among the MS.

We used a range of 1.0 to 10.0% of baseline emissions, where the baseline is N_2O emissions from managed soils in the 2012 national inventory reports (2014 submission).

The mitigation potential at Member State level (kt CO_2e/y) is shown in Figure 53. The mitigation potential per ha at Member State level (kt CO_2e/y/ha) is shown in Figure 54. The mitigation potential is related to the baseline emissions of N_2O in NIRs, so MSs with high N_2O emissions from managed soils have high potential to mitigate those emissions.

Figure 53: Mitigation potential at Member State level, kt CO_2e/y

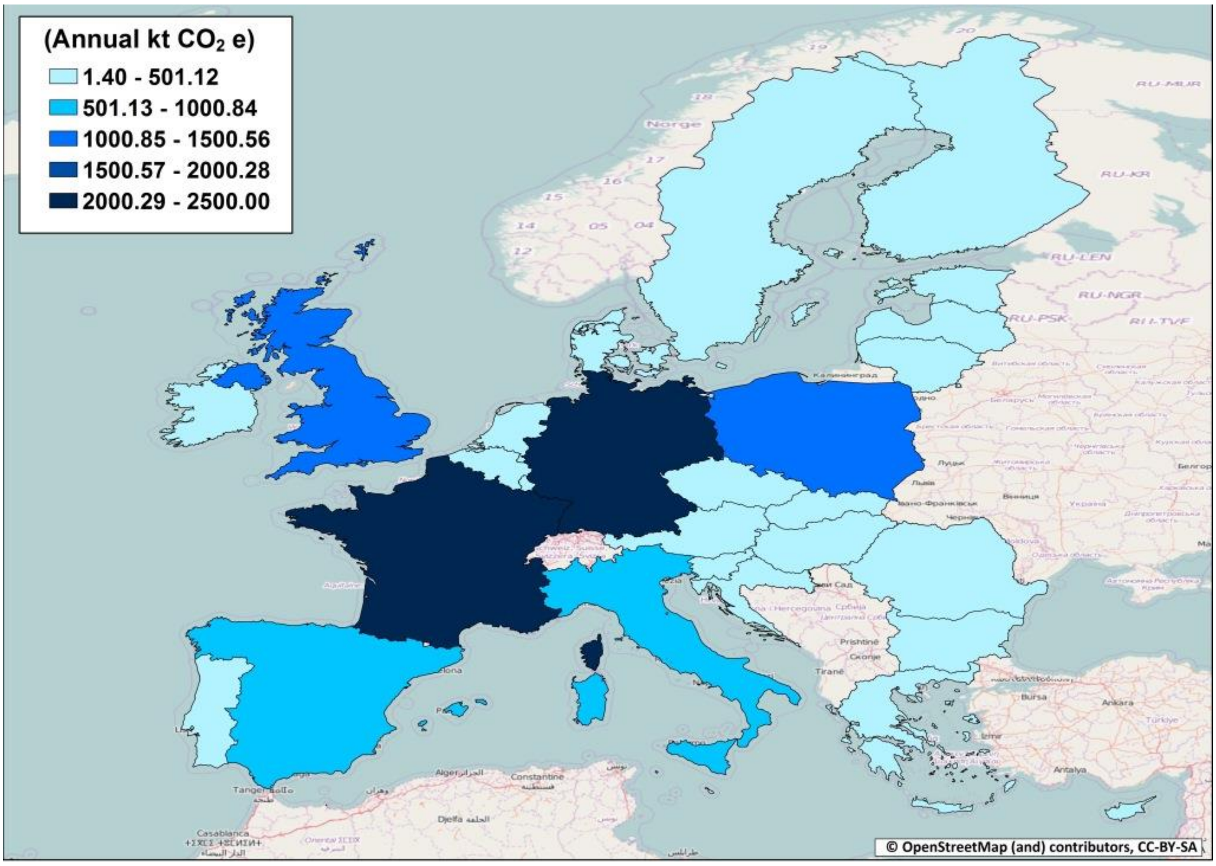
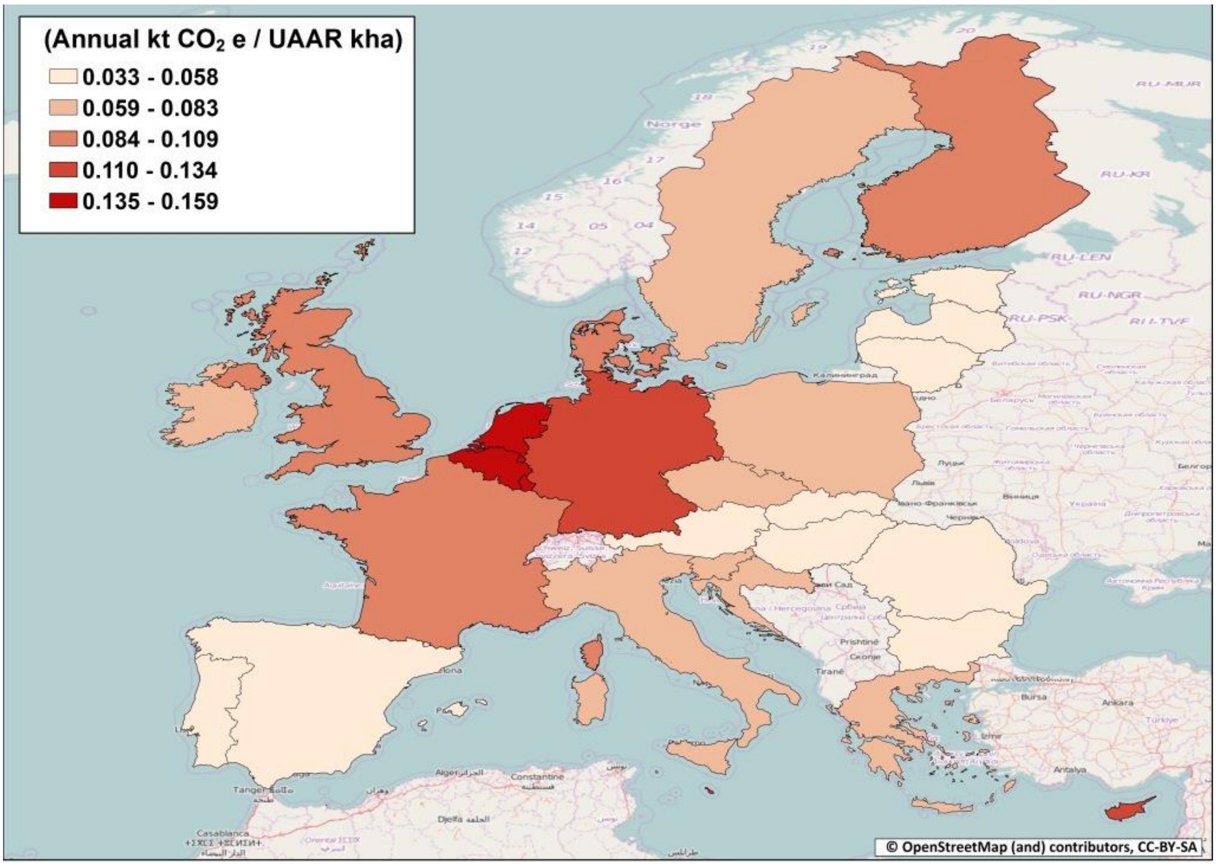


Figure 54: Mitigation potential per ha at Member State level, kt CO_2e/kha/y



Environmental co-benefits and risks of the MA

The main additional environmental benefit of this action is the reduction in nitrate leaching as a result of reduced use of N fertilizers, with consequent benefits for:

- reduced nitrate pollution of water courses.

There are unlikely to be any risks to the environment or for displacement of production because the aim of the action is to optimise the use all sources of N on the farm while maintaining yield levels.

Technological and socio-cultural barriers

There are no technological barriers to implementation and some of the management actions are already widely used by farmers to comply with requirements in Nitrate Vulnerable Zones. There is some scope for further technological development (Moorby *et al.,* 2007) which would depend upon the development of accurate and reliable weather forecasts and on the successful breeding of cultivars that can utilise N more efficiently.

The use of an appropriate nutrient management plan (see Soil and nutrient management plans) is a useful way of identifying the farm-level changes required to improve nitrogen efficiency.

Costs/business benefits to land managers of implementing the MA at farm/forest level

Optimising the use of all sources of N will require additional management time (compared to 'just in case' over-application of mineral N fertilizers), and technical advisory input and possibly soil analysis may also be required. Implementation of the plans may lead to savings in fertilizer costs (through using nutrients more efficiently).

Farmers could choose to implement this climate mitigation action in the short-term (before 2020), but individual decisions will be influenced by the economic impact on the farm business and possibly other factors.

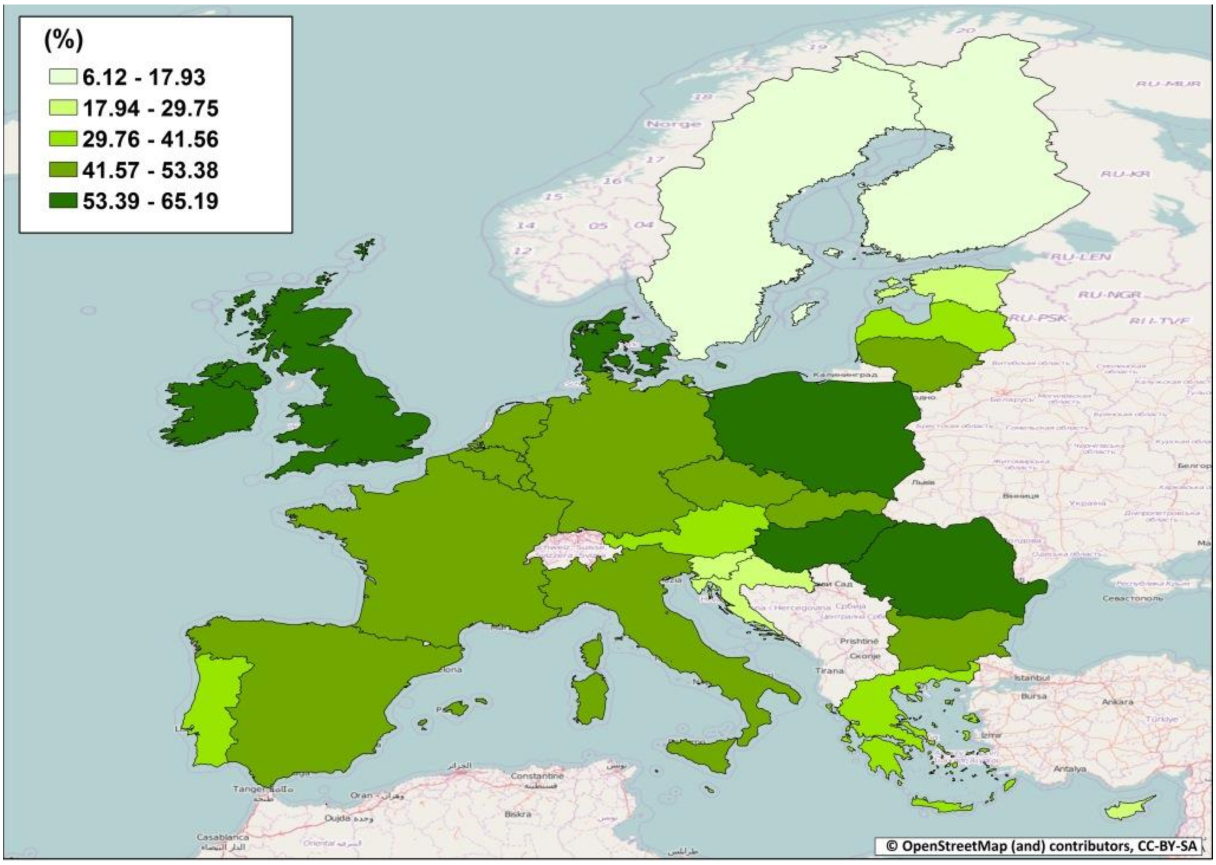
Geographic relevance

Improved nitrogen efficiency is possible on almost all farmed land (albeit with low mitigation where there is little N applied or added through grazing). The utilisable agricultural area as a percentage of total MS area is shown in Figure 55.

In NVZs, soils and nutrients are well managed, but there may be some (small) scope for further improvement. On land that is non-NVZ and non-LFA, we would expect greater scope for improvement because current uptake is judged to be lower than in NVZs, and N is usually applied. In LFAs, we expect a lower level of improvement because there is less application of N (often little or no inorganic N is applied and much of the grassland is grazed with little spreading of manure from housed livestock).

Alongside the uptake factor we have an abatement potential range that is very wide (1% to 10% of N_2O emissions from managed soils) reflecting small abatement potential in NVZs and larger potential in non-NVZs.

Figure 55: Utilisable agricultural area as a percentage of total area for each Member State



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 44.

Table 44: Summary of reporting issues for improved nitrogen efficiency

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	No Nitrous oxide (N_2O) emissions occur as a consequence of applying plant-available N to crops. Improving N efficiency may not change the total amount of N applied, and effects on N_2O emissions are highly uncertain.
Is there a methodology that will show specific impact of the mitigation action? What is it?	No
Categories	Direct N_2O emissions from managed soils

	Indirect N_2O emissions from managed soils
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Agricultural soils
Which Member States included this as a Key Category in their 2014 National Inventory Reports	26 MSs: AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,FR,HR,IE,IT,LT,LU,LV,MT,NL,PL, PT,RO,SE,SI,SK,UK
Tiers used	Tier 1: 23 MSs AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,HR,IT,LT,LU,LV,MT,PL,PT,RO, SE,SI,SK,UK Tier 2: 5 MSs ES,FR,HU,IE,NL Tier 3: 0 MSs Not specified: 0 MSs
Limitations of the Inventory reporting structure	Emissions of N_2O are highly variable, both temporally and spatially, so they are difficult to estimate or model, and it is not practical to measure emissions except in limited experimental areas. The Tier 1 and 2 methods use emission factors related to the quantity of N applied, so do not account for variation in time of application, type of fertilizer of other material containing N, or other efficiency measures that do not change the quantity of N applied.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

The measure level reports and analyses of the 2007 to 2013 RDPs are too broad brush to permit identification of this climate mitigation action and no summary information is available on the 2015 to 2020 RDPs. Some Member States will have promoted the efficient use of N fertilizers through the use RDP funded advisory services (especially in Nitrate Vulnerable Zones) and through promoting or requiring the use of nutrient management planning tools in schemes supported by other RDP measures.

Relevant CAP measures to promote the more efficient use of nitrogen, in addition to the cross-compliance requirements of SMR 1 (Nitrates Directive), could include:

- demonstration activities and information actions (M 1.2)
- setting up farm and forestry advisory services (M 2.2) to provide through the Member State's Farm Advisory Service information on: GHG emissions of the relevant farming practices; on the contribution of the agricultural sector to mitigation through improved farming and agroforestry practices; and on how to improve and optimise soil carbon levels[32].

[32] This information is an option for Member States, not a required part of the Farm Advisory Service. Article 12.3 and Annex 1 of Regulation (EU) 1306/2013

Biological N fixation in rotations and in grass mixes

Description

Nitrogen fixing crops form symbiotic relationships with bacteria in the soil that allows them to fix atmospheric N and utilise it to give a competitive advantage when N is limiting. Such crops (legumes) can fix in excess of 300 kg N/ha/y making the N input comparable with N fertilizer applications. Legumes also provide N to subsequent crops and are a useful break crop in arable rotations as well as offering potential biodiversity benefits (Rees *et al.,* 2014; Bues *et al.,* 2013; cited in Frelih-Larsen *et al.,* 2014).

This mitigation action is considered with respect to its potential for reducing emissions of N_2O, through decreased application of N fertilizer. The action can be implemented by growing a greater proportion of N fixing crops in a rotation, or including more legumes (e.g. clover species) in pasture.

Mode of action

The inclusion of legumes in arable rotations and grass swards can mitigate GHG emissions in three main ways:

- Reducing or eliminating the need for mineral N fertilizers on the fields where the legumes are grown reduces direct emissions from N fertilizers.
- The breakdown of legume residues releases N over the following growing season and reduces the amount of fertilizer-N that needs to be applied to the following crop.
- By reducing the need for mineral N fertilizers, GHG emissions from fertilizer manufacture are also reduced. However, this aspect is not considered further here because the saved emissions often occur in a different location, and sometimes in different countries, including countries outside of the EU.

Mitigation potential

Influencing factors

The effectiveness is likely to vary across the EU due to differing potentials in the range of legumes that can be grown and on the vigour of legume growth. For example, two legume crops, soya and lupins, can only be grown in warmer climates.

The effectiveness of legumes in fixing N, and reducing the need for N fertilizer, will depend to some extent on how well the legume crop is grown and the extent to which the farmer has confidence in the residual N value of the crop.

Table 45: Summary of influencing factors for biological N fixation in rotations and in grass mixes

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Arable and grass production systems.
Which soil types is this MA relevant to?	Any.
Which climatic zones is this MA relevant to?	Any.

Values

The approach offers considerable mitigation potential. For example, if legumes can be introduced to an additional 20% of the farmed area, either as replacements for non-leguminous crops or established within grass swards, then GHG emissions from N fertilizer manufacture and application may be reduced by up to 20%.

Including clover in grassland was considered to potentially reduce GHG emissions by 15 to 32% by Feliciano *et al.,* (2013) in Scotland.

The large abatement potential is for N_2O emissions in the year in which the legume is grown (applying to the area of non-leguminous crops which is replaced by legumes), and the following year when he supply of N from legume crop residues decreases the need for applied N. Often, no N fertilizer will be needed in the year the legume is grown, with a 100% reduction of N_2O emissions compared with those from the average N application to arable crops in the MS.

For grassland there is some uncertainty over the reduction in N fertilizer use that may accrue from introducing clover. The use of legumes to fix N can eliminate the need for N fertilizer altogether. However, clover grows more slowly in early spring than grass and will also cease to grow earlier in the autumn than grass. Hence in some grassland systems small amounts of N fertilizer may be applied in early spring or autumn to enable grazing to take place. Firm data on actual fertilizer N application to grass/clover swards are scarce so we have made conservative estimates of the reduction in N fertilizer use to between 60 and 80%.

We used a range of 60 to 80% of baseline emissions for grassland, where the baseline is N_2O emissions from managed soils for the additional legume area in the 2012 national inventory reports (2014 submission). For arable land, we used a range of 100 to 120% of baseline emissions, where the baseline is N_2O emissions from managed soils for the additional legume area in the 2012 national inventory reports (2014 submission).

The mitigation potential at Member State level (ktCO_2e/y) is shown in Figure 56. The mitigation potential per ha at Member State level (kt CO_2e/y/ha) is shown in Figure 57.

Figure 56: Mitigation potential at Member State level, kt CO_2e/y

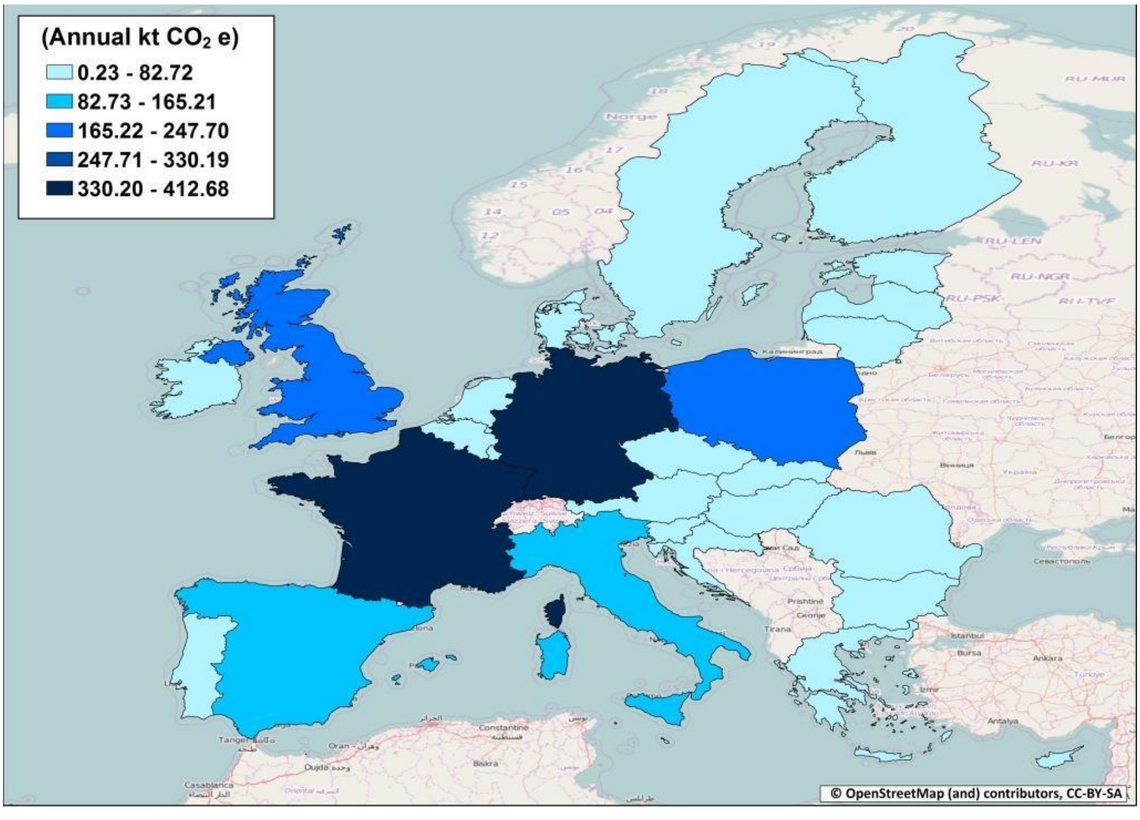
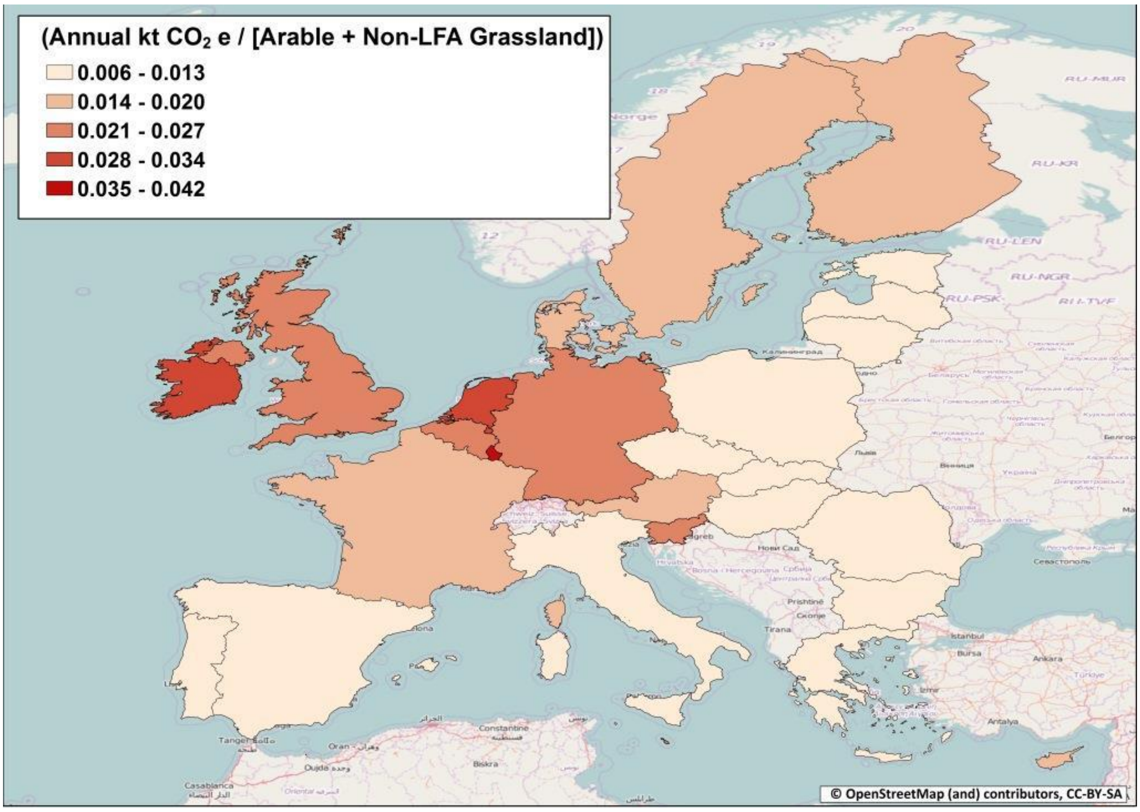


Figure 57: Mitigation potential at Member State level, kt CO_2e/kha/y



Environmental co-benefits and risks of the MA

There are other environmental benefits of agroforestry, additional to the effect on GHG emissions. These benefits could include:

- reduced nitrate leaching as a result of using less N fertilizer, with consequent benefits for water quality;
- biodiversity benefits, particularly for insect pollinators as a result of increased availability of flowering legumes as food sources;
- on arable farms greater structural diversity of farmland habitats and landscapes;
- more diverse soil microbial communities and improved soil fertility.

There are also risks to GHG emissions as a result of the changes to arable production. These risks could include:

- increases in the area of grain legumes reducing overall farm production, which could lead to increased production elsewhere, possibly in regions where GHG emissions per tonne of crop produced are greater than in the EU.

Technological and socio-cultural barriers

The use of clover/grass pastures is a well-established practice and can produce forage yields as great as those obtained using intensively fertilized all-grass swards, but there is a perception among farmers that grass/clover swards require greater management skill than all-grass pastures.

In arable systems the achievement of climate mitigation benefits and savings in fertilizer costs will depend partly on the extent to which the farmer has confidence in the residual N value of the crop.

Costs/business benefits to land managers of implementing the MA at farm/forest level

In arable systems introducing legumes into the rotation can offer opportunities for improved pest control and reduced N fertilizer use, but there are potential disadvantages too, for example if the late harvest of field beans and lupins prevents early sowing of subsequent winter cereal crops and thereby reduces yields of the following cereal crop.

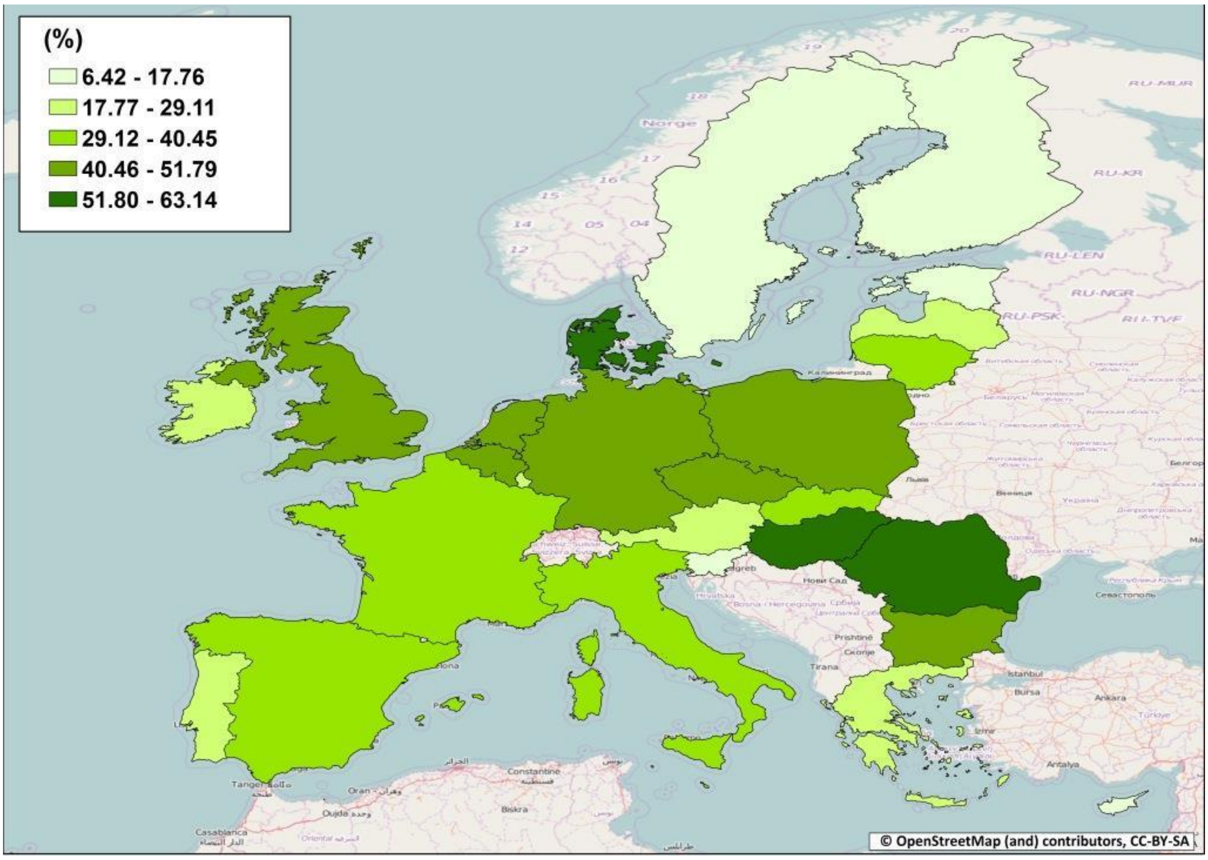
Recent research on the farm-level benefits of crop rotations showed increased gross margins due to the cost-savings, mainly from applying less mineral fertilizer, and assuming that the crops included in the rotation should be profitable on their own. The extent to which gross margin may change depends on a variety of factors that are regionally specific, including the crop rotation regime applied, the variation in mineral fertilizer (as well as pesticide and herbicide) reduction, and costs associated with implementation. Also the effect will differ depending on the specific crop rotation design and whether the crops selected require new or different equipment (involving investment or contractor costs) which may reduce the potential net savings. In determining average values for the EU of gross margin impacts, this depends on whether high, middle or low yield scenarios are considered. The range of outcomes shows that practicing crop rotations with legumes may increase gross margin by between 76.90 and 80.70 €/ha, and on average it is estimated that gross margin will increase by 78.90 €/ha (SmartSOIL, 2015).

Farmers could choose to implement this climate mitigation action in the short-term (before 2020), but individual decisions will be influenced by the economic impact on the farm business and possibly other factors.

Geographic relevance

Biological N fixation in rotations and in grass mixes will be related to area of arable and grassland (excluding LFAs). LFAs (e.g. upland areas) tend to have less N applied because the farming systems are less intensive than elsewhere, so the potential mitigation is low. The percentage of arable and grassland (non-LFA) is shown in Figure 58.

Figure 58: Land in arable or grassland production (excluding LFAs) as a percentage of total area for each Member State



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 46.

Table 46: Summary of reporting issues for biological N fixation in rotations and in grass mixes

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	No Biological nitrogen fixation is not included as a direct source of N_2O because of the lack of evidence of significant emissions arising from the fixation process. Nitrous oxide (N_2O) emissions also occur as a consequence of applying plant-available N to crops. This source is likely to be influenced by including more N-fixing crops in rotations and in grass mixes. However, the effect is highly uncertain.
Is there a methodology that will show specific impact of the mitigation action?	No

What is it?	
Categories	Direct N_2O emissions from managed soils Indirect N_2O emissions from managed soils
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Agricultural soils
Which Member States included this as a Key Category in their 2014 National Inventory Reports	26 MSs: AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,FR,HR,IE,IT,LT,LU,LV,MT,NL,PL, PT,RO,SE,SI,SK,UK
Tiers used	Tier 1: 23 MSs AT,BE,BG,CY,CZ,DE,DK,EE,EL,FI,HR,IT,LT,LU,LV,MT,PL, PT,RO,SE,SI,SK,UK Tier 2: 5 MSs ES,FR,HU,IE,NL Tier 3: 0 MSs Not specified: 0 MSs
Limitations of the Inventory reporting structure	Emissions of N_2O are highly variable, both temporally and spatially, so they are difficult to estimate or model, and it is not practical to measure emissions except in limited experimental areas. The Tier 1 and 2 methods use emission factors related to the quantity of N applied, which may be influenced by this mitigation action, but the effect is difficult to predict.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

The measure level reports and analyses of the 2007 to 2013 RDPs are too broad brush to permit identification of this climate mitigation action and no summary information is available on the 2015 to 2020 RDPs, but in the 2007 to 2013 RDPs some Member States, such as France, used the agri-environment measure (M214) to support diversification of rotations in arable crops[33].

The most significant policy change affecting this climate mitigation action was the introduction of CAP greening requirements from 2015, providing the opportunity for Member States to offer N-fixing crops as an EFA choice. This was the most popular EFA element of all, chosen by all 28 Member States except Denmark[34]. It is important to note that uptake at farm-level is not yet known and will not necessarily be linked to the introduction of legumes into arable rotations, as existing N-fixing crops will count as EFA. Also, there is a degree of flexibility in relation to the rules that are put in place to inform Member States how some of these elements are to be implemented in practice. For nitrogen fixing crops, Member States have a choice to make

[33] Source: ENRD Annex 1 - Collection of examples of the Knowledge Transfer & Innovation Focus Group http://enrd.ec.europa.eu/sites/enrd/files/fms/pdf/B16C6E54-95D9-07B8-6EC1-4CA9D6E42519.pdf
[34] Source: European Commission (2015)

about the types of crops permitted, as well as where, when and how they can be grown (i.e. whether fertilizers and pesticides are permitted and when the crops must be in the ground). These rules will have an impact on the degree to which their climate mitigation potential is realised in practice.

Where it is appropriate to promote this action, and the CAP requirements for verification and control can be met, the relevant CAP measures could include:

- under Pillar 1 greening requirements, crop diversification and use of N-fixing crops as EFAs
- demonstration activities and information (M 1.2)
- agri-environment-climate payments, as equivalence for EFAs (M10.1)

References

Feliciano, D., Hunter, C., Slee, B. and Smith, P. (2013) Selecting land-based mitigation practices to reduce GHG emissions from the rural land use sector: A case study of North East Scotland, *Journal of Environmental Management*, 120, 93-104.

Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu, J.L., Lasorella, M.V. and Longhitano, D. (2014). “Mainstreaming climate change into rural development policy post 2013.” Final report. Ecologic Institute, Berlin.

Pronk,A.A, Bijttebier J., Ten Berge, H.,RuysschaertG., Hijbeek R., Rijk, B., Werner M., Raschke I., Steinmann, H.H., Zylowska, K.,Schlatter N., Guzmán G., Syp A., Bechini L., Turpin N., Guiffant N.,Perret, E., Mauhé, N., Toqué, C., Zavattaro L., Costamagna C., Grignani, C., Lehninen, T., Baumgarten, A.,Spiegel, H., Portero, A.,Van Walleghem, T.,Pedrera, A., Laguna, A., Vanderlinden, K.,Giráldez, V., Verhagen A. (2015) Compatibility of Agricultural Management Practices and Types of Farming in the EU to enhance ClimateChange Mitigation and Soil Health List of Drivers and Barriers governing Soil Management by Farmers, including CostAspects Catch-C project Deliverable 4.434 http://www.catch-c.eu/deliverables/D4.434_List_Drivers_Barriers.pdf

SmartSOIL(2015) SmartSOIL Factsheet: Increasing soil organic matter through improved crop rotation, http://smartsoil.eu/fileadmin/www.smartsoil.eu/WP5/Factsheets/SmartSOIL_facksheet_cover-rotations_final2_print.pdf

Carbon auditing tools

Description

Carbon auditing tools encourage attention to detail and promote good practice, at the same time as highlighting areas where there may be cost efficiency savings for the farmer. The basic principle follows the saying “what gets measured, gets managed” and involves collecting data which are converted using emission factors to produce a number measured in CO_2 equivalents (CO_2e). This may be CO_2e per year, project, area or product. There are a wide range of tools to choose from varying in terms of scope, accuracy and emissions factors and those tools can be relatively easily further developed and ‘tailored’ for the need of the ‘measure’ or to country or regional specific requirements.

Mode of action

Carbon auditing tools provide a way of finding out where the largest GHG emissions arise. This then gives a breakdown of carbon sources and indicates emission hotspots which can be targeted for reduction.

The mode of action is not to directly impact GHG emissions, but rather to identify practices and changes to practices that decrease GHG emissions. The information gained encourages an economic assessment of the possible mitigation options, showing the direct implications for the farming business. There may also be financial benefits associated with competiveness and market access, through positive environmental credentials.

We note that use of carbon auditing tools will identify many mitigation actions including others considered in this work. Thus, the mitigation potential includes mitigation potential that is possible by implementation of other mitigation actions considered in this document. There is likely to be a bias towards mitigation that is economically advantageous.

Mitigation potential

Influencing factors

The potential effectiveness of the action will vary according to the nature of the farm, being greatest on those that use large amounts of N fertilizer and/or manure and have ruminant livestock.

As stated by Frelih-Larsen *et al.,* (2014), “The aim of the carbon audit is to define which mitigation actions are suitable for the farm, quantify the GHG reduction potential and prioritise the mitigation actions. To assess the GHG reduction achieved, a second carbon audit has to be done 3 to 5 years later”.

Table 47: Summary of influencing factors for carbon auditing tools

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	All
Which soil types is this MA relevant to?	All
Which climatic zones is this MA relevant to?	All

Values

Within the Frelih-Larsen *et al.,* (2014) report it is stated that 'generally, drawing up an action plan at farm level can result in a GHG emissions reduction potential of at least 10% (AgriClimateChange network of farms) for a wide range of farming systems in Europe (dairy milk farms, cereals, olives, vineyards, etc.)'. The Frelih-Larsen *et al.,* (2014) report goes on to say that 'the mitigation effect could be 10% average reduction potential in a 3 year period (AgriClimateChange 2013), or 20% reduction potential in a 5 year action plan (Holmes *et al.,* 2008)'.

We used a range of 10 to 20% of baseline emissions, where the baseline is the emissions total for agriculture in the 2012 national inventory reports (2014 submission).

The mitigation potential at Member State level, CO_2e/y and CO_2e/y/ha is shown in Figure 59 and Figure 60 respectively.

Figure 59: Mitigation potential at Member State level, kt CO_2e/y

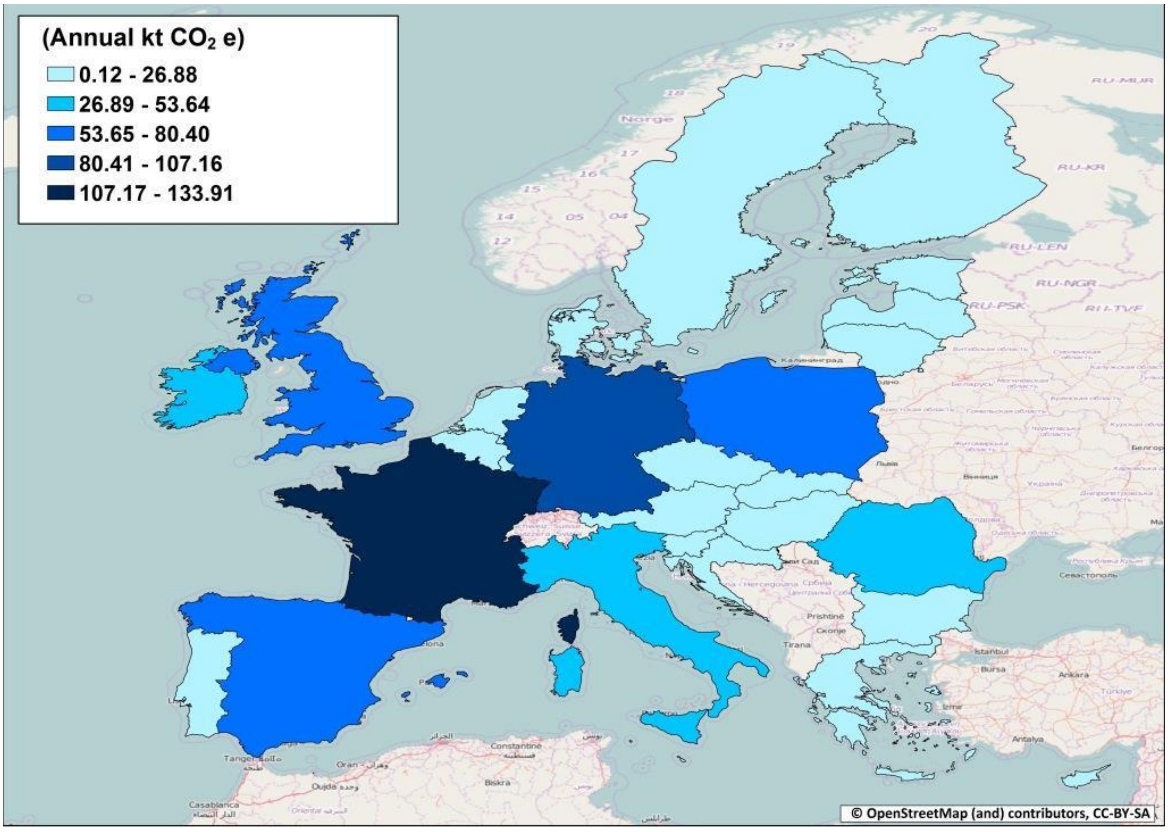
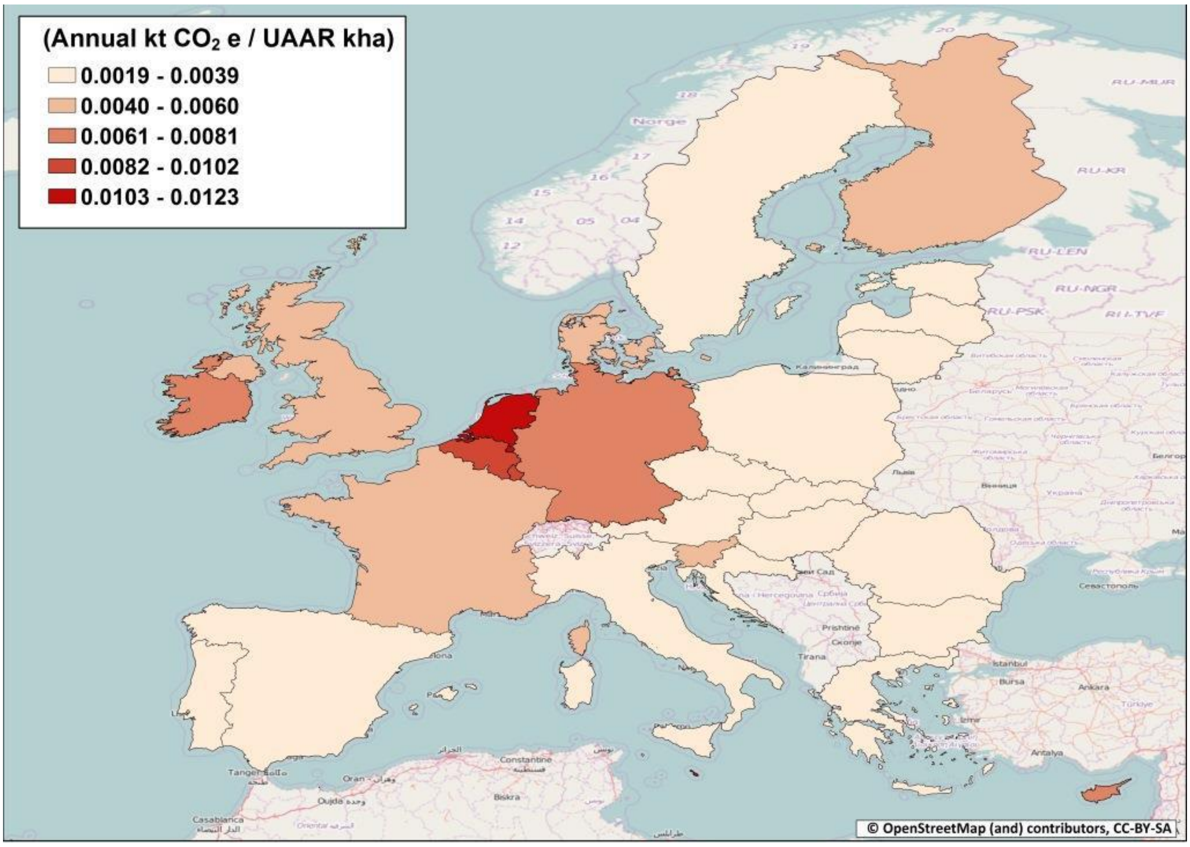


Figure 60: Mitigation potential at Member State level, kt CO_2e/kha/y



Environmental co-benefits and risks of the MA

There are other environmental benefits of this action, additional to the effect on GHG emissions, but these depend not on the use of the tool but on the effect of subsequent action to reduce GHG emissions. These benefits could include:

- less risk of diffuse pollution from N fertilizers and manure/slurry, if the audit leads to more accurate applications of fertilizers that are matched crop requirements

Risks to the environment from carbon audits are unlikely, unless the tool used does not alert the user to possible unintended environmental consequences of actions taken on the farm to reduce GHG emissions (for example planting energy crops on valuable semi-natural habitats).

Technological and socio-cultural barriers

Carbon auditing tools are a relatively novel IT based technology and although readily available there are large differences between existing tools. There is a need for technological development to ensure comparability and effectiveness, and for clearly defined methodological guidelines.

The extent of uptake of carbon auditing by farmers is not known, but may be lower among smaller or economically marginal farms.

Costs/business benefits to land managers of implementing the MA at farm/forest level

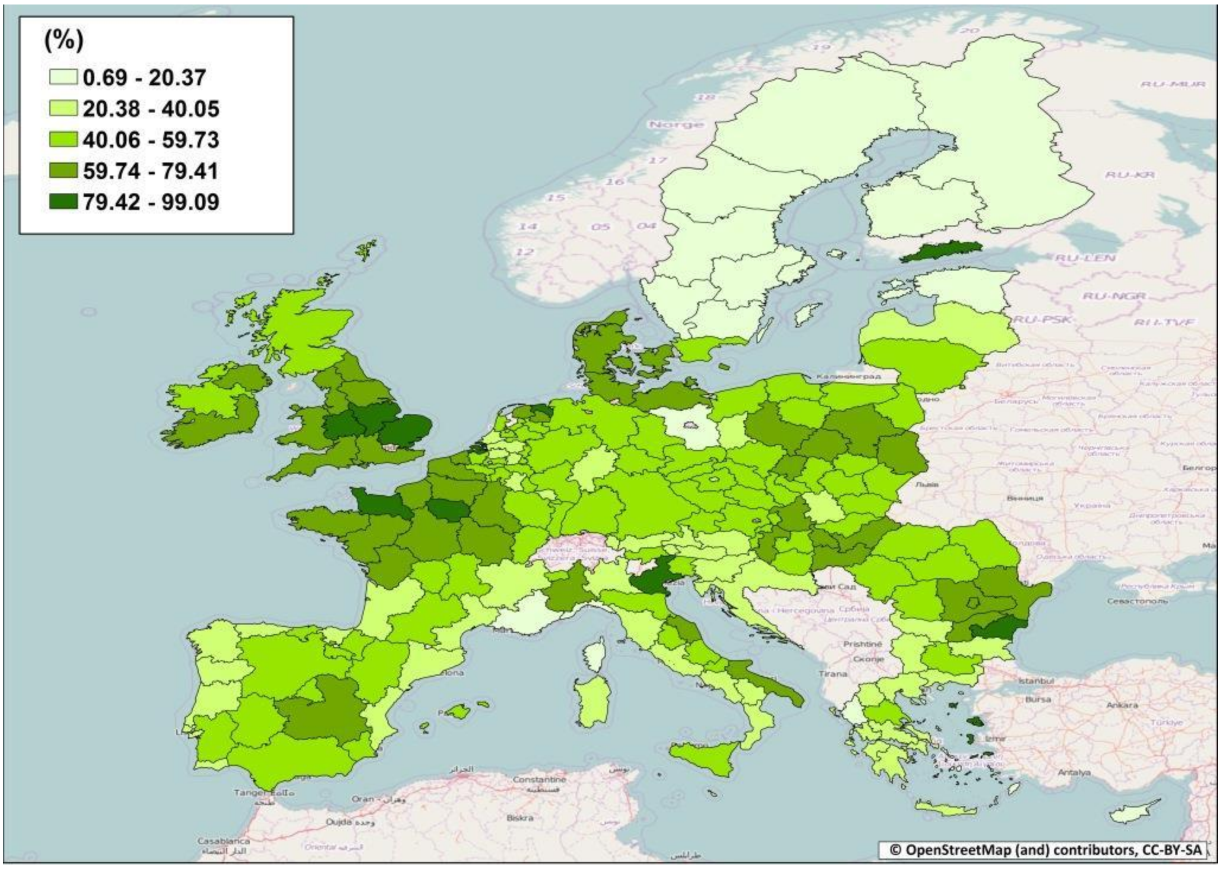
The initial cost to the business is relatively modest, covering the tools themselves and the time required to gather and input the data. The cost of subsequent action to reduce GHG emissions (e.g. driver training, investment in more fuel-efficient equipment or improved manure/slurry storage, more efficient use of N fertilizers) and the subsequent savings (e.g. reduced fuel and fertilizer costs) will vary significantly from farm to farm. Carbon auditing tools can also be used for C-footprinting and as a basis for C-labelling which might be of economic value to farmers in the future, but in the absence of a system of trading carbon emissions there may be no direct business benefit.

Farmers could choose to implement this climate mitigation action in the short-term (before 2020), but implementation of subsequent actions and repeat audits may be medium term, especially if significant investment is required.

Geographic relevance

The effectiveness of carbon auditing tools as a climate mitigation action will be related to the area of land currently in agricultural production. The land currently in agricultural production is shown in Figure 61 as the percentage of land area in agricultural production.

Figure 61: Land in agricultural production as a percentage of total area for each NUTS 2 region



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 48.

Table 48: Summary of reporting issues for carbon auditing tools

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will	No

result in a reduction in the inventory?	There is no direct mitigation because this action is a means of identifying further actions that will result in a GHG reduction.
Is there a methodology that will show specific impact of the mitigation action? What is it?	No
Categories	None
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	None
Which Member States included this as a Key Category in their 2014 National Inventory Reports	Not applicable
Tiers used	Not applicable
Limitations of the Inventory reporting structure	Not applicable

Policy measures that could be or have been used to encourage implementation of the MA in the EU

No examples were found of publicly-funded support for the use of carbon audit tools by farmers, but it is possible that carbon auditing may have been promoted by government advisory services.

Relevant CAP measures to promote the use of carbon audits include:

- demonstration activities and information (M 1.2)
- setting up farm and forestry advisory services (M 2.2) to provide through the Member State's Farm Advisory Service information on: GHG emissions of the relevant farming practices; on the contribution of the agricultural sector to mitigation through improved farming and agroforestry practices; and on how to improve and optimise soil carbon levels[35]
- possibly EIP operational groups and pilot projects (M 16.2)

References

Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu,

[35] This information is an option for Member States, not a required part of the Farm Advisory Service. Article 12.3 and Annex 1 of Regulation (EU) 1306/2013

J.L., Lasorella, M.V., Longhitano,D (2014). “Mainstreaming climate change into rural development policy post 2013.” Final report. Ecologic Institute, Berlin.

Improved on-farm energy efficiency

Description

Energy is used on farms for field operations (e.g. soil cultivation, spraying, harvesting), on-farm transport, crop storage (heating or cooling, ventilation), water pumping, glasshouse heating, animal house heating and ventilation, and many other uses. Best available technology, good equipment maintenance, and appropriate operation of equipment (e.g. speed of mobile machinery) can improve energy efficiency, leading to less fossil fuel use and less emission of greenhouse gases.

Mode of action

This mitigation action is considered with respect to its potential for reducing emissions of CO_2 through decreased combustion of fuels for farm machinery and equipment.

Mitigation potential

Influencing factors

The GHG emissions from the production of new machinery could be taken into account.

Table 49: Summary of influencing factors for improved on-farm energy efficiency

Relevance to farming systems, soil types and climatic zones	
Which farming sectors/systems is this MA relevant to?	Can be applied in any cropping or livestock system.
Which soil types is this MA relevant to?	Any
Which climatic zones is this MA relevant to?	Any

Values

Estimates derived from a MACC curve indicate that emissions from on-farm energy use could be reduced by *c*. 25% by improving energy efficiency.

A UK study (Defra Project EC0103) produced a marginal abatement cost curve (MACC) for energy emissions from energy use in the Agriculture sector. When reported by activity across sectors the greatest emissions arose from:

- Field operations 1571 kt CO_2, (35% of total), with large emissions arising from beef and sheep production as well as arable.
- Heating 1208 kt CO_2, (27% of total), of both greenhouses and livestock buildings.
- Grain drying 886 kt CO_2, (19% of total).

No other activities accounted for more than 5% of total emissions.

Output from the MACC model indicates that with the adoption of abatement techniques there is potential for cost-effective abatement of GHGs arising from energy use on farms of *c*. 1150 x 10^3 t CO_2 (26% of current emissions) by 2030 in addition to the reduction in emissions predicted from decarbonisation of the electricity supply.

The greatest cost-effective reductions may be made by the protected horticulture sector (560 kt CO_2), arable (326 kt CO_2) and poultry (177 kt CO_2) sectors, with the remaining sectors accounting for *c*. 8% of the potential reduction. There are very few opportunities for cost-effective reduction in the beef and sheep sector which has an estimated abatement potential of just 2% of the 2030 total.

The abatement potential was estimated from the data on the feasible reduction in energy use by proven approaches to increasing the efficiency with which energy is used by farm equipment reported in the UK MACC for the abatement of CO_2 emissions arising from energy use in agriculture in the UK.

In summary, we used a range of 10 to 20% of baseline emissions, where the baseline is the CO_2 emissions from energy, fuel combustion, other sectors, Agriculture/Forestry/Fisheries, in the 2012 national inventory reports (2014 submission). This baseline includes energy use in fisheries, and so is an over-estimate.

The mitigation potential at Member State level (kt CO_2e/y) is shown in Figure 62. The mitigation potential at Member State level (kt CO_2e/y/ha of utilisable agricultural area) is shown in Figure 63.

Figure 62: Mitigation potential at Member State level, kt CO_2e/y

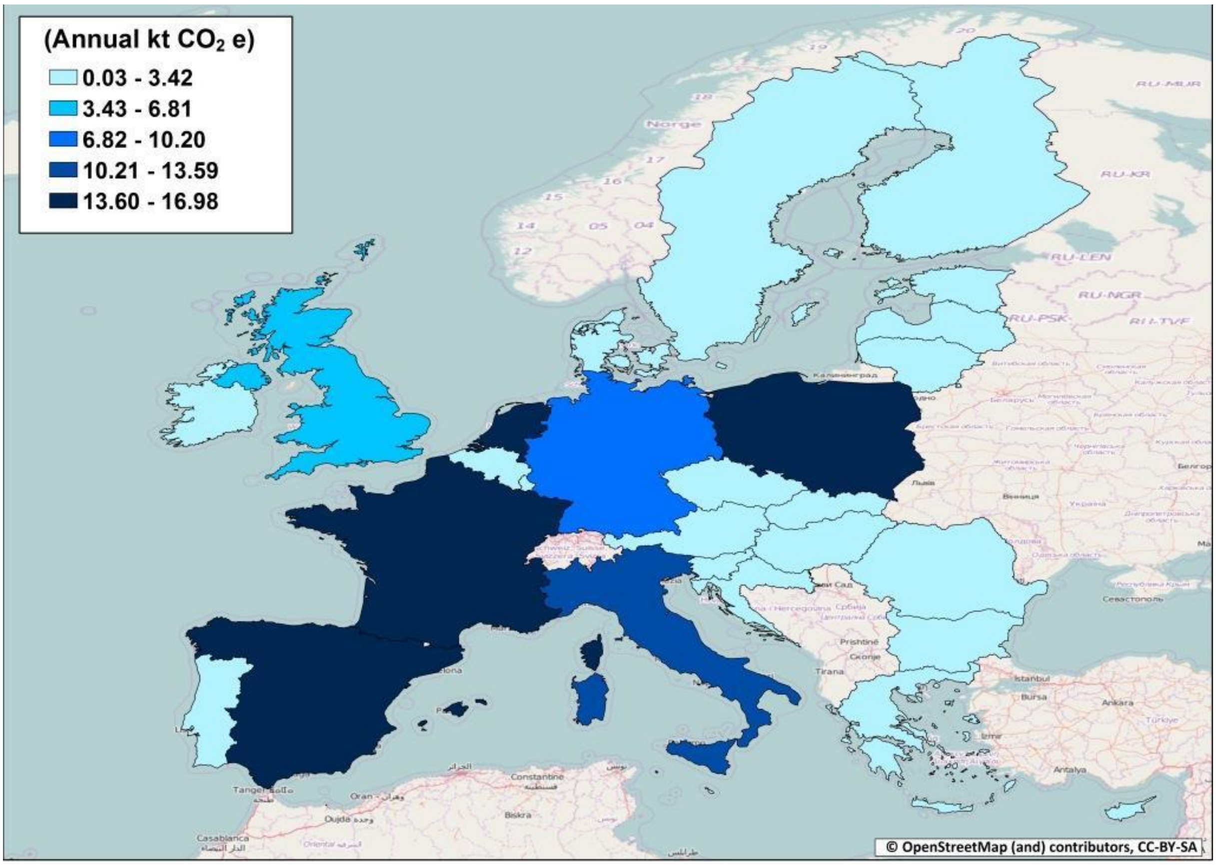
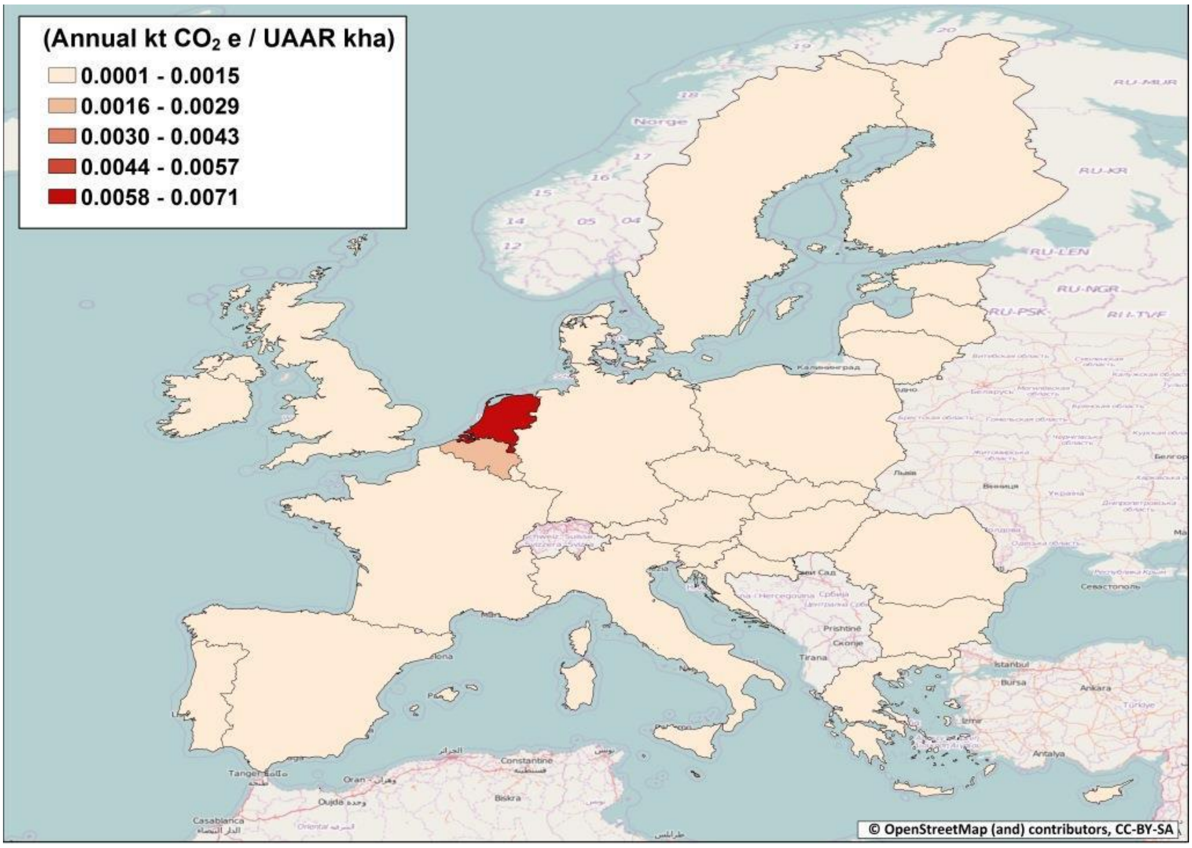


Figure 63: Mitigation potential at Member State level, kt CO_2e/kha/y



Environmental co-benefits and risks of the MA

Improving on-farm energy efficiency is unlikely to lead to any environmental benefits or risks in addition to the climate mitigation benefits from increased efficiency of production.

Technological and socio-cultural barriers

There are no technological barriers to improving energy efficiency but the value of the approach may not always be well appreciated or understood. For example, operators often think that the current equipment is working close to optimum performance and, in the case of field equipment, the need to get a task completed means that the detailed set up and matching requirements may not be properly considered.

The use of a suitably calibrated carbon calculator (see Carbon auditing tools) could help to give farmers an accurate indication of machinery performance.

Costs/business benefits to land managers of implementing the MA at farm/forest level

The costs of improving energy efficiency on the farm will vary depending on the equipment currently in use, with less potential for energy savings on farms already using modern, energy-efficient machines. For individual farmers costs may range from staff training (for example in fuel-efficient operation of field equipment) to major investment in new more energy-efficient machinery.

Farmers could choose to implement this climate mitigation action in the short-term (before 2020), but individual decisions will be influenced by the economic impact on the farm business particularly where major investment is required.

Geographic relevance

The effectiveness of energy efficiency as a climate mitigation action will be related to the area of land currently in agricultural production. The land currently in agricultural production is shown in Figure 64 as the percentage of land area of MSs in agricultural production, and in Figure 65 as the percentage of NUTS 2 land areas in agricultural production.

Figure 64: Land in agricultural production as a percentage of total area for each Member State

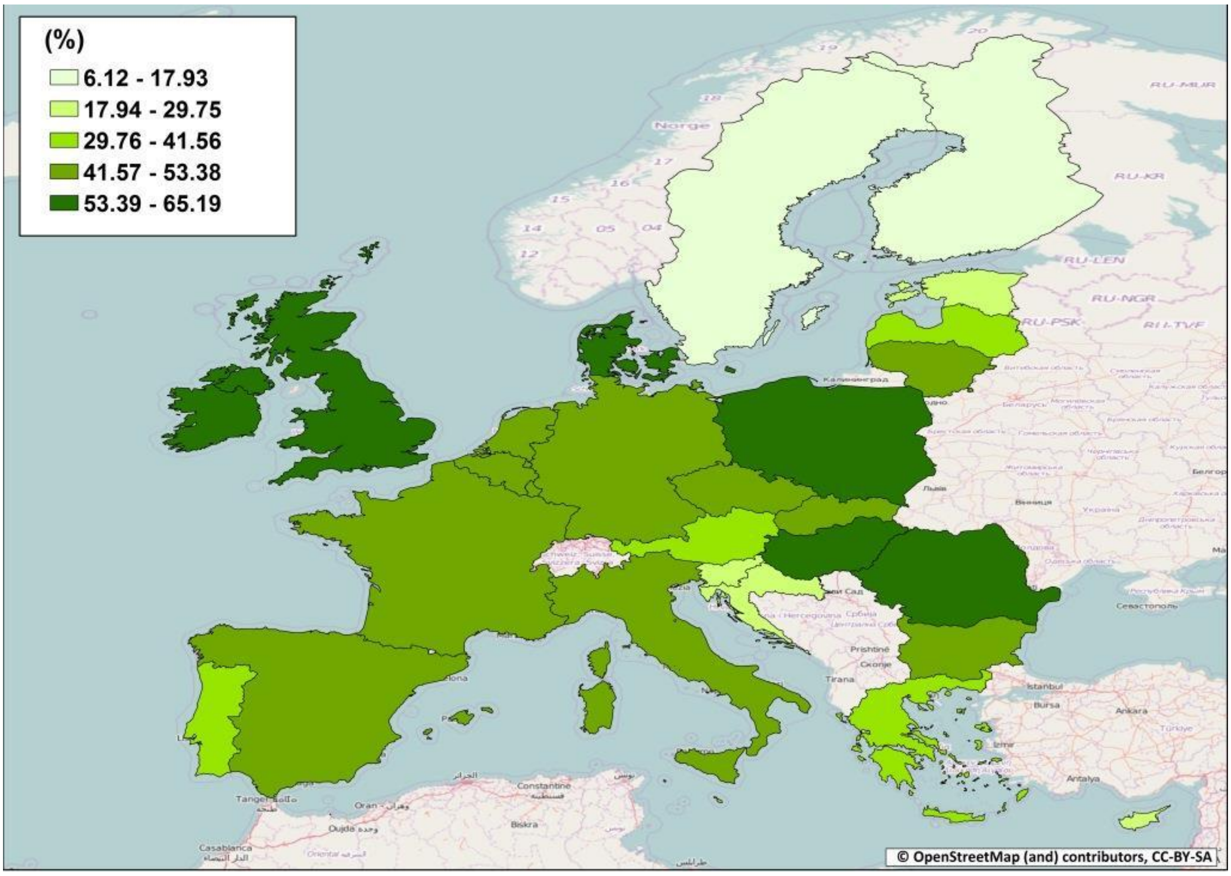
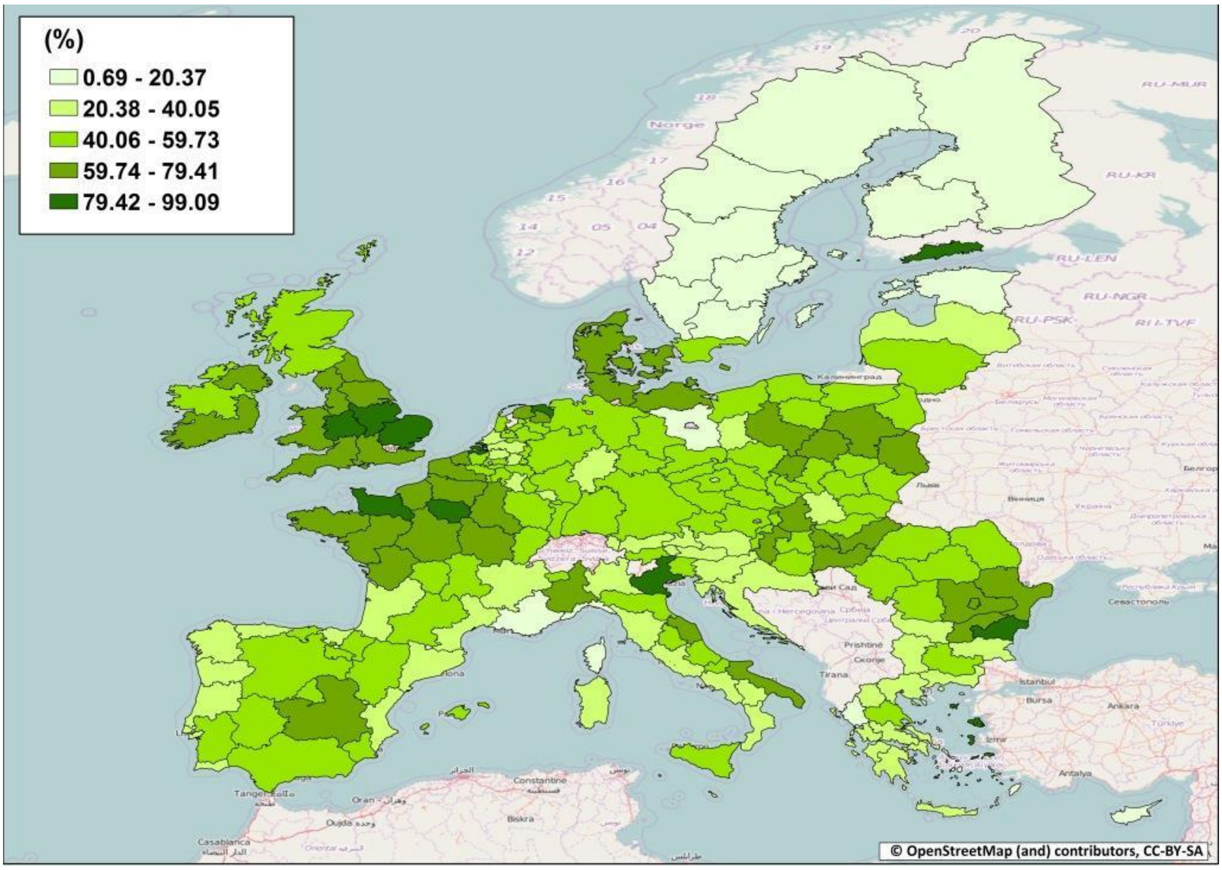


Figure 65: Land in agricultural production as a percentage of total area for each NUTS 2 region



Reporting of the mitigation effect

A summary of how the mitigation from implementation of this action is reported in national inventory reports, is given in Table 50.

Table 50: Summary of reporting issues for improved on-farm energy efficiency

Summary of how the impact of this mitigation action is shown using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories	
Is there a GHG reduction that will result in a reduction in the inventory?	Yes Mitigation may be through decreased use of electricity (e.g. for heating, cooling, ventilation, crop storage etc.) or through savings in fuel for transport and farm operations using mobile machines. The reduction in the inventory will not be disaggregated from the emissions from the total, but the saving can be calculated by other means.
Is there a methodology that will show specific impact of the mitigation action? What is it?	Yes 1. For savings in electricity use: Refer to 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Vol 2 Ch 2, Fuel Combustion Activities, 1A1A Public electricity and heat production. Tiers 1, 2 and 3 can all be used; the accuracy increases with tier. Tier 1: The effect of the Mitigation Action is not detectable because the emissions estimates are based on livestock numbers and default emission factors.

	Tier 2: This more complex method uses emission factors specific to the country and can show the effect of the Mitigation Action. Tier 3: Modelling and/or measurements are used and the effect of the Mitigation Action is expected to be detectable. 2. For savings in fuel use in mobile machines: Vol 2, Ch 3, Fuel Combustion Activities, 1A4C Other Sectors. Tiers 1, 2 and 3 can all be used; the accuracy increases with tier. Tier 1: The effect of the Mitigation Action is not detectable because the emissions estimates are based on livestock numbers and default emission factors. Tier 2: This more complex method uses emission factors specific to the country and can show the effect of the Mitigation Action. Tier 3: Modelling and/or measurements are used and the effect of the Mitigation Action is expected to be detectable.
Categories	Fuel Combustion Activities - Energy Industries Fuel Combustion Activities - Other Sectors
Summary of how the impact of this mitigation action is shown in the 2014 submission of National Greenhouse Gas inventories, using the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories	
Categories	Public Electricity and Heat Production Other Transportation
Which Member States included this as a Key Category in their 2014 National Inventory Reports	1. Public Electricity and Heat Production 25 MSs: AT,BE,BG,CY,CZ,DE,EE,EL,ES,FI,FR,IE,IT,LT,LU,LV,MT,NL,PL,PT,RO, SE,SI,SK,UK 2. Other Transportation 11 MSs: AT,BG,DE,ES,FI,FR,HU,IE,IT,LT,LU
Tiers used	1. Public Electricity and Heat Production Tier 1: 9 MSs BE,DE,DK,EE,HR,HU,LT,NL,RO Tier 2: 11 MSsAT,BG,CY,EL,FR,LU,LV,PT,SE,SK,UK Tier 3: 5 MSs CZ,FI,IE,IT,SI Not specified or not applicable: 3 MS 2. Other transportation Tier 1: 16 MSsBE,CY,DE,DK,EE,EL,HR,HU,LT,LU,MT,NL,PL,RO,SI,SK Tier 2: 7 MSs AT,BG,FR,IT,LV,PT,SE Tier 3: 4 MSs CZ,FI,IE,UK

	Not specified or not applicable: 1 MS
Limitations of the Inventory reporting structure	Baseline data include energy use in fisheries, which is not disaggregated from agriculture and forestry.

Policy measures that could be or have been used to encourage implementation of the MA in the EU

The measure level reports and analyses of the 2007 to 2013 RDPs are too broad brush to permit identification of this climate mitigation action and no summary information is available on the 2015 to 2020 RDPs, but examples of the use of the training and farm modernisation measures in the 2007 to 2013 RDPs are shown in Box 4.

***Box 4: Examples of the use of RDP 2007-13 measures to improve energy efficiency*[36]**

Sweden: Promoting the energy efficient use of farm machinery:

It has been estimated that between 10-15% of fuel can be saved through so-called "eco-driving" of tractors, combine harvesters or other farm vehicles, involving improvements in driving style, such as regularly checking and changing tyre pressures according to the load on the tractor and prevailing field conditions. The training measure was used to support the development of a training package for trainers in the Swedish county of Jönköping to create the motivation and knowledge for most farmers using tractors and other diesel vehicles to drive in a more "climate smart" way. Test training was carried out with a total of 30 participants and is to be rolled out all over Sweden with the goal of reducing emissions by 10 to 15 percent in 15 years.

France, Champagne-Ardenne, 'Plan Végétal pour l'Environnement' (PVE)

In France, the farm modernisation measure is being used to combat the environmental impact of agriculture by supporting investment in precision farming equipment. At a national level the focus of the PVE is to reduce pollution from pesticides and fertilizers; reduce soil erosion; reduce the pressure on the use of water resources; and improve energy efficiency at farm level. Investment in new equipment is intended to address these environmental issues at the same time as helping farmers gain an economic advantage in the market. The government is partly funding this programme in conjunction with local authorities and water agencies. Investments can be between €4,000 and €30,000 (up to €80,000 for cooperative farms).

Although the programme has a detailed list of eligibility requirements, some regions found that their financial resources were insufficient to cope with demand. In Champagne-Ardenne, the PVE was so successful in its first year that many applications had to be turned down. A more stringent application system has now been put in place. This prioritises investment in precision equipment for planting hedgerows as the top priority, alongside investments to reduce the use of pesticides.

Where it is appropriate to promote this action, and the requirements for verification and control can be met, the relevant CAP measures could include:

- vocational training and skills acquisition (M1.1) for example in techniques to improve fuel efficiency such as eco-driving and tractor maintenance

[36] Source: based on a review by the ENRD of Member States' RDPs post Health Check, carried out in 2009/10.

- demonstration activities and information (M 1.2), for example on developing a fuel use action plan
- setting up farm and forestry advisory services (M 2.2) to provide through the Member State's Farm Advisory Service information on: GHG emissions of the relevant farming practices; on the contribution of the agricultural sector to mitigation through improved farming and agroforestry practices; and on how to improve and optimise soil carbon levels[37]
- possibly support for investments in infrastructure related to the development, modernisation or adaptation of agriculture and forestry (M4.3)

References

Defra Project EC0103 (2010) Energy Marginal Abatement Cost Curve for Agricultural Sector, http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17631

[37] This information is an option for Member States, not a required part of the Farm Advisory Service. Article 12.3 and Annex 1 of Regulation (EU) 1306/2013

4 Mitigation potential by Member State

4.1 Introduction

Mitigation potential for each MA, in each MS can, theoretically, be estimated by the following equation:

$$MP = AP \times A_t \times U$$

Where:

- MP = annual mitigation potential (kg CO_2e per MS)
- AP = annual abatement potential (kg CO_2e /ha or kg CO_2e per head of livestock)
- A_t = total applicable area of land or total applicable head of livestock (ha or number)
- U = uptake factor (proportion of land area or livestock number expected to take up the MA)

Abatement potential values have been obtained through the review work in this project, and are given in chapter 3 for each MA. Applicable area of land or number of livestock were obtained from available data on areas of land in different agricultural systems (e.g. area of arable land) or numbers of livestock by species.

The applicable land or livestock types were largely self-evident: e.g. reduced tillage of land is mainly applicable to arable production systems.

The uptake factor (proportion) could not be obtained from available data sets at the time of this work, because we had no information on the current uptake level for each MA, and poor information on likely policy support in the future (see “data limitations” in section 4.2). Therefore, we provide a decision tree to indicate new analysis needed to obtain data, and we used expert judgement to estimate uptake factors so that the equation above could be applied to estimate mitigation potential, albeit with low confidence.

The purpose of this chapter is to:

- Provide an outline method for robust estimation of mitigation potential by MA and MS, together with notes on the data limitations (section 4.2);
- Provide estimates of mitigation potential for each MA and MS, based on meta review outputs for abatement potential and expert judgement for uptake potential (section 4.3).

The table of mitigation potential in section 4.3 should be used alongside the overview of MAs in section 0, and more detailed information on each MA in chapter 3.

Besides the care needed in the use of mitigation potential values based on expert judgement of uptake factors, particular care is needed in the interpretation of mitigation potential values from multiple MAs. This is because the mitigation potential of implementation of multiple MAs is not necessarily the sum of the mitigation potential values given for the MAs individually. Some MAs are mutually exclusive, some may have synergistic or additive effects when implemented together, and some may have overlapping mitigation potential, for example, if they mitigate the same sources of emissions. This aspect is considered in more detail in section 4.2.

4.2 A method for mitigation assessment by Member State and data limitations

Overview

Here we provide an outline method for robust estimation of mitigation potential by MA and MS, together with notes on the data limitations. We provide decision trees that can be followed to estimate mitigation potential. Then, we explain the data limitations that have prevented the application of these methods in this project, before going on to cover the interaction between MAs, to help show how mitigation potential may be influenced by simultaneous implementation of multiple MAs.

Method

Chapter 3 has identified for each of the climate MAs the mitigation potential, reporting opportunities, geographical relevance, environmental co-benefits and risks, technological and socio-cultural barriers, the costs/benefits to the farm/forest business and the CAP policy measures that MSs could use to encourage increased uptake of each measure. Additionally, Chapter 6 identifies the scale of additional administrative effort required by managing authorities to increase uptake of mitigation using different types of CAP measures.

That information is a key part of the evidence and knowledge base required to make decisions at MS or NUTS 2 level about the most appropriate and cost-effective ways of using CAP measures to improve climate mitigation. In reality, for managing authorities and others, the assessment of *realistic* opportunities to improve mitigation from agriculture and forestry is complicated. It requires making judgements about how the factors identified in this report will apply in practice in specific MSs and regions (for example, assessing the effect of farmer attitudes, existing uptake of technology, relevant markets and supply chains).

In deciding how to improve mitigation MSs or regions also have to take into account the other policy priorities and objectives which make demands on their CAP resources and, in the short-term at least, consider how these resources have already been deployed and how farmers have responded to the choices available to them (for example choice of RDP measures and greening requirements). To make most cost-effective use of available CAP funds, a MS will wish to compare not just the climate benefits of increased uptake of the different climate MAs that are relevant to their agricultural and forest sectors, but also the additional costs that would be incurred. Again, these will vary from region to region, particularly in the case of compensation payments.

To support this process of estimating uptake, mitigation potential, cost of improving implementation of specific climate mitigation actions at MS/RDP/NUTS2 level, we have provided decision trees, which also address the need to maintain existing mitigation actions where these are at risk. To make the process clearer, three different decision trees are shown, each relevant to a specific group of MAs (because the MAs within each group are supported by similar combinations of CAP measures).

The decision trees can be used to calculate the total increased mitigation potential and for each of the relevant climate MAs within a specific MS or region, and also to compare the cost/benefit of different climate MAs as applied by the MS, in terms of €/additional tCO_2e. This could help managing authorities to choose the most cost-effective way of prioritising available resources to improve climate mitigation.

Each of the three decision trees applies to a different group of climate mitigation actions as follows:

Decision Tree 1 (Figure 66) is used for the following 11 climate MAs which can be directly supported by RDP and/or GAEC or greening measures**:**

Land use

- Conversion of arable land to grassland to sequester carbon in the soil
- New agroforestry
- Wetland/peatland conservation/ restoration
- Woodland planting
- Preventing deforestation and removal of farmland trees
- Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land

Crop production systems

- Use cover/catch crops
- Leaving crop residues on the soil surface
- Ceasing to burn crop residues and vegetation

Manure, fertiliser and soil management

- Soil and nutrient management plans
- Biological N fixation in rotations and in grass mixes

Decision Tree 2 (Figure 67**) is used for the following three climate MAs** which can be supported by CAP knowledge transfer/advisory services and/or other RDP measures:

Crop production systems

- Reduced tillage
- Zero tillage

Energy

- Improved on-farm energy efficiency

Decision Tree 3 (Figure 68**) is used for the following six climate MAs** which can be supported indirectly only by CAP knowledge transfer/advisory/innovation services and National Rural Network activities**:**

Livestock production systems

- Livestock disease management
- Use of sexed semen for breeding dairy replacements
- Feed additives for ruminant diets
- Optimised feeding strategies for livestock

Manure, fertiliser and soil management

- Improved nitrogen efficiency

Energy

- Carbon auditing tools

None of the decision trees are appropriate for the remaining two climate MAs, which cannot be supported by CAP measures: breeding lower methane emissions in ruminants and using nitrification inhibitors.

Figure 66: Decision Tree 1

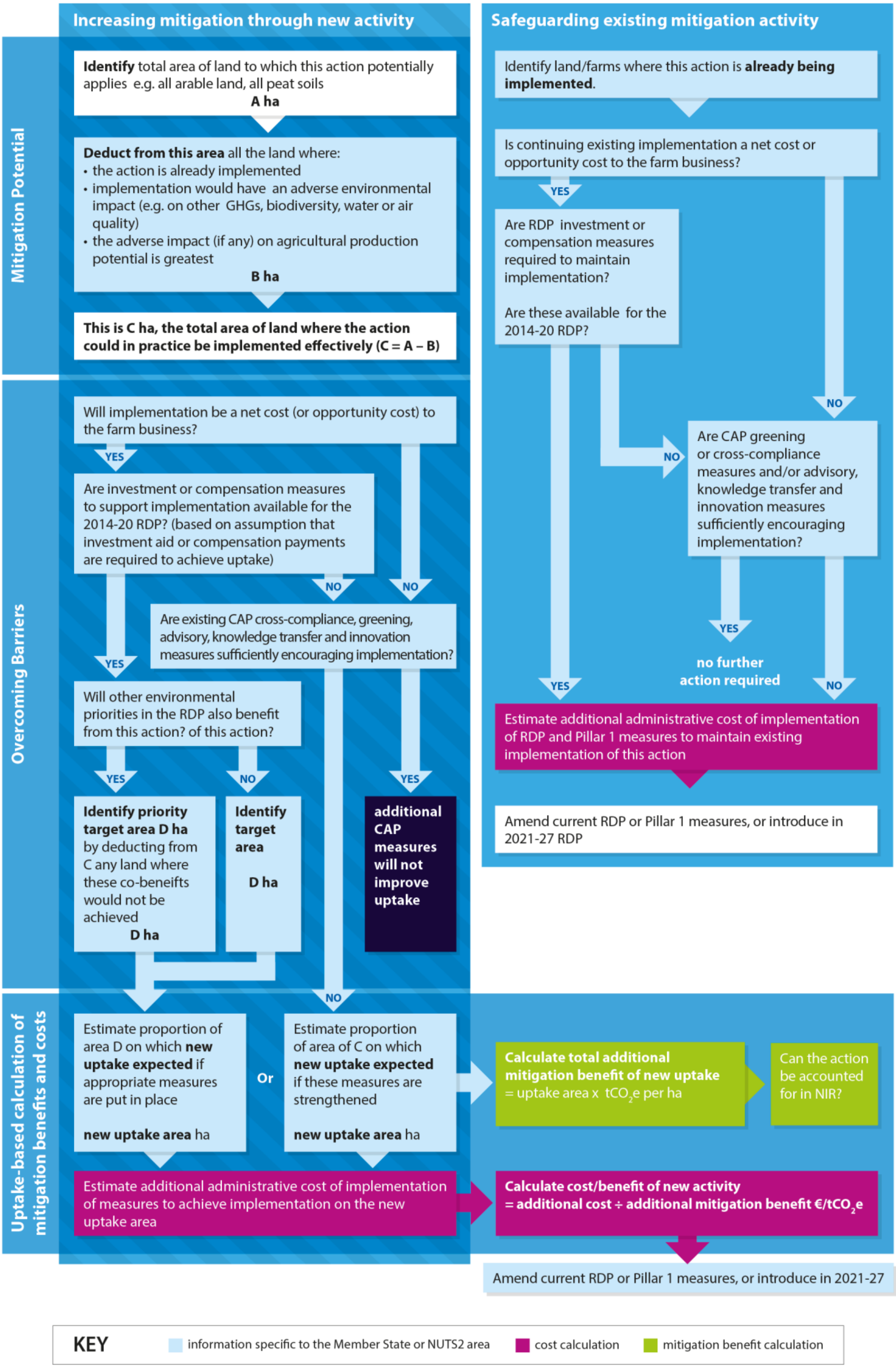


Figure 67: Decision Tree 2

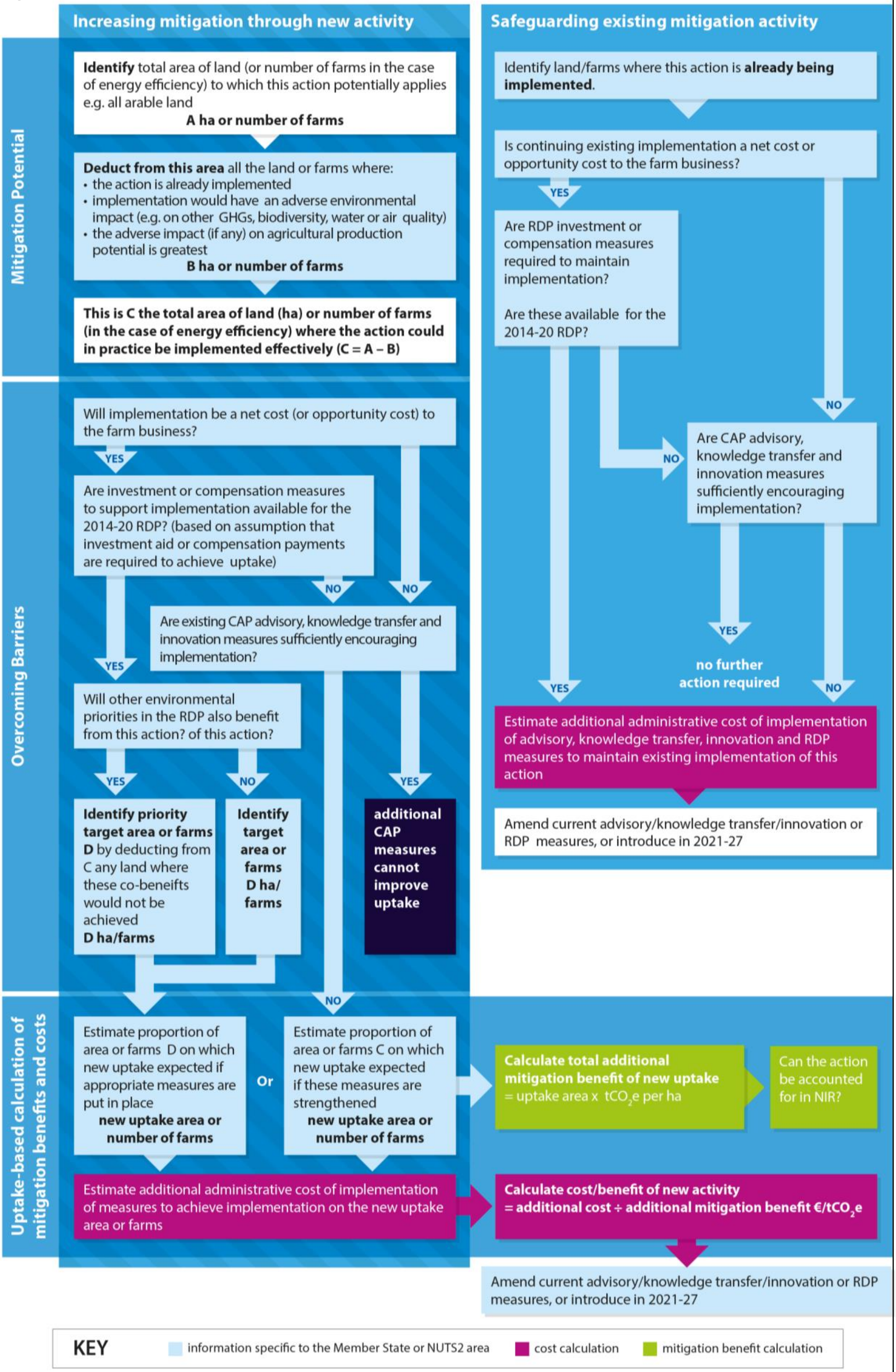
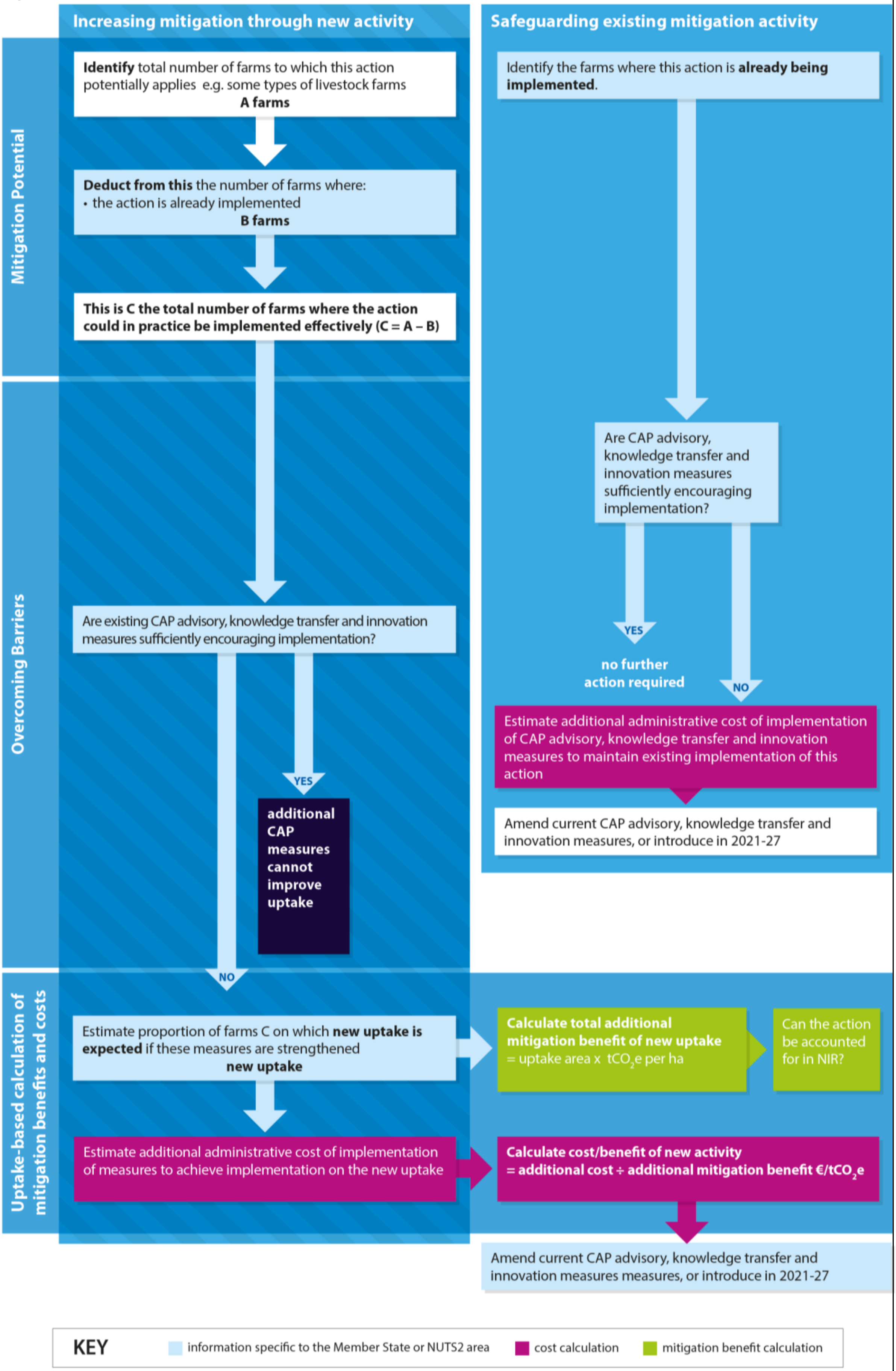


Figure 68: Decision Tree 3



Data limitations

Ideally we would have applied the processes described in the decision trees to calculate the realistic mitigation potential for each climate MA in each MS but we were unable to do this because much of the regionally specific data is not publicly available and in some cases requires analysis of agricultural and environmental authorities' own data. For example, this includes data on:

- **land/ farms already implementing the climate MA**; even if the MA has already been supported by the CAP the reporting requirements do not provide the necessary level of detail. For example the conversion of arable to grassland may have been supported by agri-environment payments in 2007 to 2013 but agri-environment uptake is reported at measure level and agri-environment programmes typically include a large number of different actions; where GAEC or greening requires buffer strips (often grassed) the extent of these is not recorded in reported data.
- **areas where implementation of the climate MA would pose a risk to other environmental priorities** (production displacement, biodiversity habitats, water quality) requires data on the location, extent and current biodiversity or agricultural quality of land within the potential uptake area, which is not available at EU level.
- **expected additional uptake by farmers** depends on many locally specific factors including existing levels of uptake, farmer capacity and attitudes to making changes, levels of payments on offer, and other factors which are often a matter of judgement for management authorities.
- **the scale of resources (financial and technical) available to the MS** will affect the scale of improved uptake that is achievable, which also depends on their ability (and willingness) to redeploy resources and change existing CAP implementation.

For this reason we were unable to use the decision trees to make detailed assessments of additional mitigation potential activity at Member State or NUTS 2 level. Instead we present mitigation potential using expert judgement for the likely uptake (See Chapter 4.4).

Interactions between mitigation actions

Throughout this study mitigation potential has been reviewed as the mitigation potential of each action reviewed independently of others and on the basis of meta-data. However, the implementation of certain actions may be complementary to others or in some instances exclude the introductions of others on the same parcel of land.

In the majority of cases, the adoption of mitigation actions (MAs) will be independent of each other and the abatement potential of any two or more MAs will be the sum of the mitigation potential of each MA.

However, there are some MAs that exclude each other. For example, options to sequester carbon from arable land include conversion to grassland or to woodland, but the same parcel of land cannot be converted to both. To some degree our assumptions (Table 54) on uptake of these actions do take this into account in assuming that it is unlikely that more than a very small proportion of arable land will be converted to either grassland or woodland so there is little scope for overlap. In such cases the abatement potential may still be considered as the sum of that of each MA.

Some MAs will overlap with each other, in particular, nutrient management plans (NMRs) and carbon auditing tools (CATs) will lead to the adoption of some discrete MAs such as improved nitrogen efficiency (NMRs) or optimised feeding strategies for livestock (CATs). As a result summing the mitigation potential of these MAs will give an abatement potential greater than is likely in practice. There are, however, circumstances where the implementation of combined actions will lead to increased mitigation benefits even if the sum of mitigation potential of each individual mitigation action is not additive.

We consider that there is little scope for antagonism among the MAs or for synergy. Those that we have identified are explained in Table 51. For example, optimising feeding strategies for livestock is likely to increase the proportion of non-grass feeds in ruminant diets thereby reducing the production of grass. Such a change may not axiomatically lead to a reduced area of grassland, as the use of N fertilizer and other inputs may decrease to allow a reduction in grass yield on an unchanged area. In addition, optimising feeding strategies may lead to an increase in stock numbers which may require additional grassland during the grazing period. Alternatively, optimising feeding strategies can also be associated with an increase in the housing period to enable greater control of the diet by reducing the uncertainties of carbohydrate and protein intake during grazing. Hence, the need to increase production of non-grass forages is likely to reduce the area needed for grassland. Reducing the need for grass (and hence grassland) will reduce the incentive for converting arable land to grassland.

In Table 51 we summarize the interactions outlined above. In the majority of cases, adoption of one MA will complement the adoption of others. We therefore only list the exceptions to keep the table succinct and easy to understand.

Table 51: Interactions between mitigation actions

Mitigation Action	Exclusive (cannot be combined with)	Overlap - reduction of abatement potential	Comments
Conversion of arable land to grassland to sequester carbon in the soil	Woodland planting. New agroforestry.	Optimised feeding strategies for livestock There may also be potential increases in grazing livestock.	If land use is changed from arable to grassland or woodland this can only be done once. Further benefit will be obtained if grassland is managed to further sequester carbon. The effect will be additive. The increased use of non-grass feeds in order to optimise feeding strategies for livestock will reduce the demand for grass and hence reduce the incentive for conversion of arable land to grassland. If livestock numbers increase then the sequestration benefits of conversion of arable land to grassland could be offset by additional livestock increasing methane production.
New agroforestry	Conversion of arable land to grassland to sequester carbon in the soil. Woodland planting.		Actions cannot all happen on the same land parcel.
Wetland/ peatland conservation/ restoration		Conversion of arable land to grassland to sequester carbon in the soil. Woodland planting.	There could be a small overlap with the conversion of arable to grassland or woodland planting if many owners decide to restore former wetlands that have been used as arable rather than converting to grassland or woodland planting.
Woodland planting	Conversion of arable land to grassland to sequester carbon in the soil. New agroforestry.		If woodlands are created this can only be done once and hence the MA cannot be used in combination with conversion of arable land to grassland or new agroforestry. New shelterbelts, hedgerows, woody buffer strips and in-field trees will not overlap with conversion of arable land to grassland but will overlap with agroforestry.
Preventing deforestation and removal of farmland trees			Not dependent on, and will not influence other actions.

Mitigation Action	Exclusive (cannot be combined with)	Overlap - reduction of abatement potential	Comments
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land			Not dependent on, and will not influence other actions.
Reduced tillage	Zero tillage		Usually farmers will choose either RT or ZT, according to soil type, rotation, climate and investment in machinery. But, RT may be used to address problems of grass weeds or compaction in ZT rather than inversion techniques.
Zero tillage	Reduced tillage		
Leaving crop residues on the soil surface		Soil and nutrient management plans	The impacts of leaving crop residues on the surface should be factored into soil and nutrient management plans
Ceasing to burn crop residues and vegetation		Leaving crop residues on the soil surface	If crop residues are no longer burned then they can be left on the soil surface. The greater challenge however will be to ensure that residues which are no longer burnt are instead removed for livestock bedding or biomass.
Use cover/catch crops		Soil and nutrient management plans. Improved nitrogen efficiency.	Soil management plans are used to reduce risks of soil erosion by wind or water and hence may to lead to the use of cover crops. The use of cover crops should be factored into nutrient management plans as well.
Livestock disease management			Not dependent on, and will not influence other actions.
Use of sexed semen for breeding dairy replacements			Not dependent on, and will not influence other actions.
Breeding lower methane emissions in ruminants			Not dependent on, and will not influence other actions.

Mitigation Action	Exclusive (cannot be combined with)	Overlap - reduction of abatement potential	Comments
Feed additives for ruminant diets		Optimised feeding strategies for livestock	The use of feed additives may be considered an addition to optimising the use of standard feed components.
Optimised feeding strategies for livestock		Conversion of arable land to grassland. Carbon auditing tools.	Optimised feeding strategies for ruminants are likely to have a reduced proportion of grass and hence will reduce the demand for grassland.
Soil and nutrient management plans		Use cover/catch crops. Carbon auditing tools. Improved nitrogen efficiency	Soil management plans are to reduce risks of soil erosion by wind or water. Both nutrient management plans and carbon auditing tools may lead to reduced inputs of N fertilizer and hence reduced emissions of N_2O.
Use of nitrification inhibitors			Since this is a new MA there is no overlaps between this MA and others.
Improved nitrogen efficiency		Carbon auditing tools. Soil and nutrient management plans.	Improved N efficiency will be recommended by both CATs and NMPs.
Biological N fixation in rotations and in grass mixes			There will not be any overlap as this MA will not be a standard recommendation in carbon auditing tools or nutrient management plans.
Carbon auditing tools		Soil and nutrient management plans. Improved nitrogen efficiency. Optimised feeding strategies for livestock. Improved on-farm energy efficiency. Feed additives for ruminant diets.	The use of carbon auditing tools should lead to the adoption of some of the individual MAs.
Improved on-farm energy efficiency		Carbon auditing tools.	

Although there may be little or no synergy or interaction among the MAs, some may be grouped or 'bundled' together in order to combine GHG abatement with improved husbandry and resource efficiency (Table 52).

Table 52: Groupings of mitigation actions

Group	Mitigation action
Arable land management	Reduced tillage
	Zero tillage
	Ceasing to burn crop residues and vegetation
	Use cover/ catch crops
	Soil and nutrient management plans
	Use of nitrification inhibitors
	Improved nitrogen efficiency
	Biological N fixation in rotations and in grass mixes
	Carbon auditing tools
	Improved on-farm energy efficiency
Grassland management	Soil and nutrient management plans
	Use of nitrification inhibitors
	Improved nitrogen efficiency
	Biological N fixation in rotations and in grass mixes
	Carbon auditing tools
	Improved on-farm energy efficiency
Livestock management	Livestock disease management
	Use of sexed semen for breeding dairy replacements
	Breeding lower methane emissions in ruminants
	Feed additives for ruminant diets
	Optimised feeding strategies for livestock
Land management	Conversion of arable land to grassland to sequester carbon in the soil
	New agroforestry
	Wetland/ peatland conservation/ restoration
Woodland management	Woodland planting
	Preventing deforestation and removal of farmland trees
	Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land

4.3 Estimated mitigation potential per percentage point of additional uptake

The table below, (on three pages) provides mitigation potential values for each MA and MS. These are the values used to draw maps earlier in this report. Values are presented to two significant figures (following convention for carbon footprint reporting), allowing presentation of values that differ by many orders of magnitude without implying excessive accuracy.

Many mitigation potential values, especially those for land use activities, are not reductions in emissions, but are dominated by sequestration of carbon in soil and/or biomass.

The values in Table 53 are the mitigation potential per percentage point of uptake. Colouring of table cells is used to emphasise differences between MAs and MSs. The colour key is as follows (kt CO_2e/y):

< 10	
10 to 99	
100 to 999	
>1000	

The mitigation potential values for different MAs cannot be summed to gain an estimate of the total potential, because many MAs mitigate the same categories of GHG emissions, and some are mutually exclusive on the same area of land. Furthermore, some MAs (Carbon auditing tools and Soil and nutrient management plans) are actions to plan and implement other mitigation actions.

Table 53: Low high and median mitigation potential values (kt CO_2e/y) for each mitigation action and each Member State

	Conversion of arable land to grassland to sequester carbon in the soil			New agroforestry			Wetland/peatland conservation/restoration			Woodland planting			Preventing deforestation and removal of farmland trees			Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land			Reduced tillage		
MS	**Low**	**High**	**Median**	**Low**	**High**	**Median**	**Low**	**High**	**Median**	**Low**	**High**	**Median**	**Low**	**High**	**Median**	**Low**	**High**	**Median**	**Low**	**High**	**Median**
AT	32	110	69	4.6	28	16	0.00074	0.0046	0.0027	46	58	52	28	280	150	14	14	14	0.26	0.78	0.52
BE	20	66	43	2.1	12	7.3	0.00056	0.0035	0.002	21	26	23	4.3	43	24	2.2	2.2	2.2	0.16	0.48	0.32
BG	74	250	160	7.7	46	27	0	0	0	77	97	87	26	260	140	13	13	13	0.6	1.8	1.2
CY	3.4	11	7.5	0.25	1.5	0.87	0	0	0	2.5	3.1	2.8	1.3	13	7.2	0.65	0.65	0.65	0.028	0.084	0.056
CZ	66	220	140	6	36	21	0.0013	0.0085	0.0049	60	75	67	20	200	110	9.8	9.8	9.8	0.54	1.6	1.1
DE	330	1100	590	29	180	88	0.017	0.11	0.063	290	370	280	83	830	440	42	42	40	2.7	8.1	4.5
DK	55	180	120	4	24	14	0.00043	0.0027	0.0016	40	50	45	3.6	36	20	1.8	1.8	1.8	0.45	1.3	0.9
EE	13	43	28	1.2	7.3	4.3	0.05	0.32	0.18	12	15	14	17	170	91	8.3	8.3	8.3	0.1	0.31	0.21
EL	72	240	160	6.4	38	22	0	0	0	64	80	72	27	270	150	13	13	13	0.59	1.8	1.2
ES	390	1300	840	38	230	130	0.00066	0.0042	0.0024	380	480	430	110	1100	580	53	53	53	3.1	9.4	6.3
FI	51	170	110	3.5	21	12	0.89	5.6	3.2	35	44	39	160	1600	900	82	82	82	0.42	1.3	0.84
FR	440	1500	960	43	260	150	0.0017	0.011	0.0062	430	540	490	110	1100	620	57	57	57	3.6	11	7.2
HR	22	73	48	2	12	6.9	0	0	0	20	25	22	16	160	86	7.8	7.8	7.8	0.18	0.54	0.36
HU	110	350	230	8.5	51	30	0.000017	0.00011	0.000063	85	110	96	14	140	78	7	7	7	0.86	2.6	1.7
IE	23	76	49	6.3	38	22	0.059	0.37	0.22	63	79	71	4.8	48	26	2.4	2.4	2.4	0.19	0.56	0.37
IT	220	750	490	21	120	73	0.0000036	0.000023	0.000013	210	260	230	71	710	390	36	36	36	1.8	5.5	3.7
LT	44	150	96	4.4	26	15	0.0056	0.035	0.02	44	55	49	15	150	85	7.7	7.7	7.7	0.36	1.1	0.72
LU	1.4	4.6	3	0.18	1.1	0.62	0	0	0	1.8	2.2	2	0.57	5.7	3.1	0.28	0.28	0.28	0.011	0.034	0.023
LV	27	89	58	2.8	17	9.9	0.024	0.15	0.088	28	35	32	22	220	120	11	11	11	0.22	0.65	0.43
MT	0.21	0.7	0.46	0.015	0.093	0.054	0	0	0	0.15	0.19	0.17	0.0063	0.063	0.035	0.0032	0.0032	0.0032	0.0017	0.0052	0.0034
NL	24	81	52	2.9	17	10	0.0012	0.0073	0.0042	29	36	32	2.7	27	15	1.3	1.3	1.3	0.2	0.59	0.39
PL	300	1000	650	25	150	88	0.0021	0.013	0.0078	250	310	280	68	680	370	34	34	34	2.4	7.3	4.9
PT	46	150	100	4.8	29	17	0	0	0	48	60	54	26	260	140	13	13	13	0.38	1.1	0.76
RO	210	690	450	21	120	72	0.0002	0.0013	0.00073	210	260	230	47	470	260	23	23	23	1.7	5.1	3.4
SE	58	190	130	4.6	27	16	0.6	3.8	2.2	46	57	51	200	2000	1100	100	100	100	0.48	1.4	0.95
SI	4.8	16	10	0.75	4.5	2.6	0	0	0	7.5	9.3	8.4	9.2	92	51	4.6	4.6	4.6	0.039	0.12	0.078
SK	33	110	71	3.2	19	11	0.0000099	0.000062	0.000036	32	40	36	14	140	79	7.1	7.1	7.1	0.27	0.8	0.53
UK	130	450	290	23	140	82	0.29	1.9	1.1	230	290	260	21	210	110	10	10	10	1.1	3.3	2.2
EU	**2800**	**9300**	**5900**	**280**	**1700**	**950**	**1.9**	**12**	**7.1**	**2800**	**3500**	**3100**	**1100**	**11000**	**6200**	**560**	**560**	**560**	**23**	**68**	**45**

	Zero tillage			Leaving crop residues on the soil surface			Ceasing to burn crop residues and vegetation			Use cover/catch crops			Livestock disease management			Use of sexed semen for breeding dairy replacements			Breeding lower methane emissions in ruminants		
MS	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
AT	0.52	1.6	1	1.6	32	17	N/A	N/A	0.62	13	21	17	0.44	4.4	2.4	0.32	1.1	0.72	0.15	0.31	0.23
BE	0.32	0.96	0.64	0.98	20	10	N/A	N/A	0	7.9	13	10	0.57	5.7	3.2	0.36	1.3	0.81	0.17	0.33	0.25
BG	1.2	3.6	2.4	3.7	74	39	N/A	N/A	34	30	49	40	0.24	2.4	1.3	0.096	0.33	0.21	0.059	0.12	0.088
CY	0.92	2.8	1.9	0.17	3.4	1.8	N/A	N/A	0.7	1.4	2.3	1.8	0.046	0.46	0.25	0.01	0.037	0.024	0.0088	0.018	0.013
CZ	1.1	3.2	2.2	3.3	66	35	N/A	N/A	0	26	44	35	0.32	3.2	1.7	0.23	0.79	0.51	0.098	0.2	0.15
DE	5.4	16	8.9	16	330	140	N/A	N/A	0	130	220	150	2.9	29	16	2.3	8	5.2	1	2	1.5
DK	0.9	2.7	1.8	2.8	55	29	N/A	N/A	3.4	22	37	29	0.46	4.6	2.5	0.31	1.1	0.7	0.13	0.25	0.19
EE	0.21	0.62	0.42	0.64	13	6.7	N/A	N/A	0	5.1	8.5	6.8	0.058	0.58	0.32	0.043	0.15	0.096	0.021	0.041	0.031
EL	5.1	15	10	3.6	72	38	N/A	N/A	44	29	48	39	0.41	4.1	2.3	0.089	0.31	0.2	0.15	0.31	0.23
ES	54	160	110	19	390	200	N/A	N/A	520	150	260	210	1.9	19	10	0.78	2.7	1.8	0.47	0.95	0.71
FI	0.84	2.5	1.7	2.6	51	27	N/A	N/A	0.51	21	34	27	0.22	2.2	1.2	0.087	0.3	0.19	0.04	0.08	0.06
FR	7.2	22	14	22	440	230	N/A	N/A	32	180	290	240	4.3	43	24	3.2	11	7.1	1.4	2.8	2.1
HR	0.36	1.1	0.72	1.1	22	12	N/A	N/A	0	8.8	15	12	0.13	1.3	0.73	0.074	0.26	0.17	0.039	0.079	0.059
HU	1.7	5.2	3.4	5.3	110	56	N/A	N/A	0	42	70	56	0.36	3.6	2	0.17	0.59	0.38	0.068	0.14	0.1
IE	0.37	1.1	0.74	1.1	23	12	N/A	N/A	0	9.1	15	12	1.2	12	6.3	0.98	3.4	2.2	0.44	0.87	0.65
IT	3.7	11	7.3	11	220	120	N/A	N/A	19	90	150	120	1.7	17	9.5	0.96	3.4	2.2	0.51	1	0.77
LT	0.72	2.2	1.4	2.2	44	23	N/A	N/A	0	18	30	24	0.2	2	1.1	0.14	0.49	0.31	0.058	0.12	0.087
LU	0.023	0.068	0.045	0.069	1.4	0.73	N/A	N/A	0	0.55	0.92	0.74	0.037	0.37	0.2	0.029	0.1	0.065	0.012	0.023	0.018
LV	0.43	1.3	0.87	1.3	27	14	N/A	N/A	0	11	18	14	0.091	0.91	0.5	0.071	0.25	0.16	0.034	0.067	0.05
MT	0.0034	0.01	0.0069	0.011	0.21	0.11	N/A	N/A	0	0.084	0.14	0.11	0.0054	0.054	0.03	0.0032	0.011	0.0073	0.0013	0.0025	0.0019
NL	0.39	1.2	0.79	1.2	24	13	N/A	N/A	0	9.7	16	13	1	10	5.6	0.76	2.7	1.7	0.3	0.6	0.45
PL	4.9	15	9.7	15	300	160	N/A	N/A	30	120	200	160	1.6	16	9	0.93	3.3	2.1	0.43	0.85	0.64
PT	5.9	18	12	2.3	46	24	N/A	N/A	43	19	31	25	0.41	4.1	2.2	0.22	0.78	0.5	0.13	0.26	0.2
RO	3.4	10	6.8	10	210	110	N/A	N/A	110	83	140	110	0.98	9.8	5.4	0.33	1.2	0.75	0.37	0.74	0.55
SE	0.95	2.9	1.9	2.9	58	31	N/A	N/A	43	23	39	31	0.33	3.3	1.8	0.24	0.83	0.53	0.11	0.23	0.17
SI	0.078	0.23	0.16	0.24	4.8	2.5	N/A	N/A	0	1.9	3.2	2.5	0.12	1.2	0.65	0.09	0.32	0.2	0.032	0.063	0.047
SK	0.53	1.6	1.1	1.6	33	17	N/A	N/A	0	13	22	17	0.14	1.4	0.78	0.085	0.3	0.19	0.043	0.086	0.064
UK	2.2	6.6	4.4	6.7	130	71	N/A	N/A	0	54	90	72	2.5	25	14	1.6	5.5	3.5	0.75	1.5	1.1
EU	**100**	**310**	**210**	**140**	**2800**	**1400**	**N/A**	**N/A**	**880**	**1100**	**1900**	**1500**	**23**	**230**	**120**	**14**	**50**	**32**	**7**	**14**	**11**

	Feed additives for ruminant diets			Optimised feeding strategies for livestock			Soil and nutrient management plans			Use of nitrification inhibitors			Improved nitrogen efficiency			Biological N fixation in rotations and in grass mixes			Carbon auditing tools			Improved on-farm energy efficiency		
MS	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
AT	0.8	1.6	1.2	0.23	0.69	0.46	0.61	1.5	1.1	6.7	20	13	0.31	3.1	1.7	18	37	27	7.5	15	11	0.79	1.6	1.2
BE	0.89	1.8	1.3	0.19	0.57	0.38	0.71	1.8	1.2	6.2	19	12	0.35	3.5	1.9	21	42	32	9.3	19	14	2.1	4.2	3.2
BG	0.32	0.64	0.48	0.15	0.45	0.3	0.81	2	1.4	8.4	25	17	0.4	4	2.2	24	48	36	6.5	13	9.8	0.49	0.97	0.73
CY	0.048	0.097	0.073	0.038	0.11	0.077	0.071	0.18	0.12	0.8	2.4	1.6	0.035	0.35	0.19	2.1	4.2	3.2	0.82	1.6	1.2	0.079	0.16	0.12
CZ	0.51	1	0.76	0.17	0.5	0.33	0.98	2.5	1.7	10	31	21	0.49	4.9	2.7	29	59	44	8.1	16	12	0.19	0.38	0.28
DE	5.2	10	7.8	0.7	2.1	1.4	8.2	20	14	89	270	180	4.1	41	23	250	490	370	69	140	100	6.2	12	9.3
DK	0.73	1.5	1.1	0.098	0.29	0.2	1	2.5	1.8	11	32	22	0.5	5	2.8	30	60	45	9.6	19	14	2.1	4.2	3.1
EE	0.11	0.21	0.16	0.027	0.08	0.054	0.15	0.37	0.26	1.5	4.5	3	0.075	0.75	0.41	4.5	9	6.7	1.3	2.7	2	0.25	0.5	0.38
EL	0.78	1.6	1.2	0.15	0.45	0.3	0.96	2.4	1.7	7.5	22	15	0.48	4.8	2.6	29	58	43	9.1	18	14	0.87	1.7	1.3
ES	2.6	5.1	3.8	0.38	1.1	0.76	3.6	9.1	6.4	34	100	69	1.8	18	10	110	220	160	38	75	57	11	22	16
FI	0.39	0.77	0.58	0.1	0.31	0.21	0.7	1.7	1.2	7.5	22	15	0.35	3.5	1.9	21	42	31	5.7	11	8.6	1.5	3	2.3
FR	7.1	14	11	1.2	3.7	2.5	9.2	23	16	85	250	170	4.6	46	25	280	550	410	89	180	130	11	23	17
HR	0.21	0.42	0.31	0.073	0.22	0.15	0.41	1	0.73	4.3	13	8.6	0.21	2.1	1.1	12	25	19	3.4	6.8	5.1	0.67	1.3	1
HU	0.38	0.75	0.56	0.21	0.64	0.43	1	2.5	1.8	11	33	22	0.51	5.1	2.8	31	61	46	8.7	17	13	0.87	1.7	1.3
IE	2.2	4.4	3.3	0.12	0.35	0.23	1.3	3.2	2.3	8.5	25	17	0.65	6.5	3.5	39	77	58	18	36	27	0.69	1.4	1
IT	2.7	5.3	4	0.88	2.6	1.8	3.3	8.3	5.8	34	100	68	1.7	17	9.1	100	200	150	35	71	53	6.8	14	10
LT	0.3	0.59	0.44	0.066	0.2	0.13	0.62	1.6	1.1	6.6	20	13	0.31	3.1	1.7	19	37	28	5.1	10	7.6	0.1	0.2	0.15
LU	0.06	0.12	0.09	0.0081	0.024	0.016	0.061	0.15	0.11	0.56	1.7	1.1	0.03	0.3	0.17	1.8	3.6	2.7	0.67	1.3	1	0.051	0.1	0.077
LV	0.17	0.34	0.26	0.031	0.092	0.061	0.3	0.76	0.53	3.2	9.6	6.4	0.15	1.5	0.83	9.1	18	14	2.4	4.8	3.6	0.37	0.75	0.56
MT	0.0072	0.014	0.011	0.00094	0.0028	0.0019	0.0051	0.013	0.0089	0.057	0.17	0.11	0.0025	0.025	0.014	0.15	0.3	0.23	0.079	0.16	0.12	0.023	0.046	0.034
NL	1.6	3.3	2.5	0.25	0.76	0.5	1.1	2.9	2	10	31	21	0.57	5.7	3.1	34	69	51	16	32	24	9.2	18	14
PL	2.2	4.5	3.4	1.2	3.7	2.4	4.1	10	7.1	45	130	89	2	20	11	120	240	180	37	73	55	10	21	16
PT	0.68	1.4	1	0.073	0.22	0.15	0.59	1.5	1	4.8	14	9.6	0.29	2.9	1.6	18	35	26	7.2	14	11	1	2	1.5
RO	2	4	3	0.3	0.91	0.61	1.7	4.1	2.9	17	50	33	0.83	8.3	4.6	50	99	74	18	36	27	1.2	2.3	1.7
SE	0.63	1.3	0.95	0.11	0.33	0.22	0.87	2.2	1.5	7.3	22	15	0.43	4.3	2.4	26	52	39	7.6	15	11	1.5	3	2.2
SI	0.16	0.32	0.24	0.034	0.1	0.069	0.14	0.35	0.24	1.4	4.3	2.9	0.069	0.69	0.38	4.2	8.3	6.2	1.9	3.7	2.8	0.21	0.42	0.31
SK	0.22	0.44	0.33	0.095	0.28	0.19	0.37	0.92	0.65	3.9	12	7.9	0.18	1.8	1	11	22	17	3.3	6.5	4.9	0.087	0.17	0.13
UK	3.9	7.7	5.8	0.66	2	1.3	5.4	14	9.5	47	140	94	2.7	27	15	160	330	240	52	100	78	4.2	8.4	6.3
EU	**37**	**74**	**55**	**7.6**	**23**	**15**	**48**	**120**	**84**	**470**	**1400**	**950**	**24**	**240**	**130**	**1400**	**2900**	**2200**	**470**	**940**	**710**	**74**	**150**	**110**

4.4 Estimated mitigation potential by Member State using expert judgement

Estimated uptake

Estimation of MA uptake by MSs is an essential step in the estimation of mitigation potential by MS. At the time of this work, information on current uptake for each MA was not available, so possible future uptake could be only estimated using expert judgement. For transparency, here we provide the estimated uptake values for each MA in each of the 28 MSs.

Some MAs have estimated uptake percentages that are the same in all MSs, and others have values that differ between member states, where there is information or expert knowledge to support this. The rationale for the estimates of uptake in each member state is given in Table 54. The uptake values (%) are from expert judgement of likely uptake that is additional to current uptake (which in most cases is not known). The uptake estimates take account of farm-level barriers (e.g. costs of implementation, technical barriers), but not policy barriers.

Table 54: Rationale for expert judgement of uptake values (Table 55 based on expert judgement) of MAs, that is additional to current uptake (which in most cases is not known), for each MA, with confidence rating

Mitigation action (uptake values, %)	Rationale for expert judgement of uptake values in Table 55	Confidence rating
Conversion of arable land to grassland to sequester carbon in the soil (1%)	There is reluctance at a farm scale to convert productive arable land to grassland due to cost, management constraints and lack of demand for the grass produced. Cross Compliance, Greening and Agri-environment actions also cover this action so we feel that the scope for additional uptake is low. This uptake factor is not geographically dependent.	High
New agroforestry (1%)	Agroforestry is only selected as an Ecological Focus Areas option in five MSs. Nineteen MSs selected agroforestry as an RDP measure in the 2007 to 2013 period, however relatively low uptake has been achieved. It is likely that significant increases in advice and financial incentives would be required to overcome farm barriers and improve uptake. The long term impacts on the farm mean that uptake is likely to remain relatively low.	Low

Mitigation action (uptake values, %)	Rationale for expert judgement of uptake values in Table 55	Confidence rating
Wetland/peatland conservation/restoration (1%)	**Conservation: reduced loss of wetland by 10%** Many existing wetlands should be protected from drainage by national legislation, particularly those located in Natura 2000 areas. The conservation management of some wetlands and peatlands will be supported by RDP payments or by other forms of nature conservation management. On this basis, we have assumed that there is limited scope for additional action. **Restoration: 1%** Land with high soil organic carbon is mostly highly productive arable land. There will be significant production impacts associated with re-wetting these areas, and therefore much reluctance to do so.	Medium High
Woodland planting (1%)	Grants to encourage woodland planting have been available for a number of years and our assumption is that the additional uptake will be relatively low. The appetite for converting productive agricultural land to woodland is likely to be low from an agronomic perspective.	Medium
Preventing deforestation and removal of farmland trees (1%)	Additional scope is limited due to the protection already in place for farmland trees through Cross Compliance and Greening.	Low
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land (10%)	There is scope for improvement of management practices on 10% of existing farm woodland.	Very low
Reduced tillage (5%)	The level of additional uptake is expected to be small because much implementation will have already been made where the MA is compatible with the farming system. We use a value of 5% additional uptake, from an expert view of uptake by late adopters.	Low
Zero tillage (5 to10%)	Where the benefits are smaller and less obvious the uptake should be at the lower level. A higher level of uptake is targeted for areas with high potential and where additional focus and incentivisation will lead to greater uptake.	Low

Mitigation action (uptake values, %)	Rationale for expert judgement of uptake values in Table 55	Confidence rating
Leaving crop residues on the soil surface (1%)	Preventing the removal of crop residues (through bailing and offtake) is achieved through activities such as chopping straw from cereal crops. The offtake is generally used for animal bedding which is then returned to land as manure. The scope to encourage additional levels of residues being returned is relatively low and dependent on the market for residues for bedding and biomass. The demand for crop residues from the bio-energy sector is likely to increase, creating less incentive for direct return to land.	Low
Ceasing to burn crop residues and vegetation (100%)	Burning crop residues in the field is almost completely banned in the EU. There is, therefore, very little scope to further reduce this activity; and the estimated uptake is based on total cessation of this activity.	High
Use cover/catch crops (10%)	Cover crops need to be carefully targeted in order to achieve cost-effective mitigation. This operation is unlikely to be cost-effective in areas where cultivation costs are high, or where there is a risk of yield penalties through use of the cover crop. Other potential barriers to uptake include concerns about herbicide use and resistance and the possibly negative affect of the yield of the following crop if sowing is delayed or compromised.	Medium
Livestock disease management (40 to 55%)	The richer countries are likely to have an increased numbers of vets who will be able to provide advice on how livestock health may be improved. It is stated in the screening report that 80 to 100% of UK dairy herds will have some diseased animals. It is unlikely that there will be variation in the proportion of animals that would respond to treatment amongst the MSs. A small variation in possible uptake may be seen across four groups of MSs.	Very low
Use of sexed semen for breeding dairy replacements (5 to 50%)	Availability in some MSs may be very limited, resulting in a wide range of uptake values.	Very low
Breeding lower methane emissions in ruminants (0 to 5%)	The richer countries are likely to pursue breeding programmes more readily than other member states. Availability is likely to be limited in all MSs; hence the small uptake factors.	Very low

Mitigation action (uptake values, %)	Rationale for expert judgement of uptake values in Table 55	Confidence rating
Feed additives for ruminant diets (10 to 35%)	The percent reduction was for use of supplementary fats, since that is the best documented and least controversial option. The feeds needed for this option should be available in all MSs, but technical knowledge may be limited in many. It is stated in the screening document that about 5% of French cattle farmers are already using fat supplementation. The main limiting factor is likely to be the availability of suitable fats.	Low
Optimised feeding strategies for livestock (30 to 60%)	It is difficult to determine the uptake factors for this mitigation action as some countries, for pigs and poultry at least, have already gone about as far as is technically feasible in reducing unnecessary protein intake. Therefore, the less agriculturally developed countries are likely to have greater potential for uptake since they are likely to be using less sophisticated rations. Given the extent of the changes over the last 20 years in pig and poultry diets in countries like the UK and DK there is likely to be a lot of scope in many MSs. The values provided are for the livestock industry as a whole, and take account of the greater difficulties for optimising ruminant diets.	Very low
Soil and nutrient management plans (100%)	Uptake factor is set at 100% for all MSs on the basis that better implementation of soil and nutrient management plans is possible on all farmed land. This MA is applicable in NVZs, non-NVZ land, and LFAs. In NVZs, soils and nutrients are well managed, but there may be some (small) scope for further improvement. On land that is non-NVZ and non-LFA, we would expect greater scope for improvement because current uptake is judged to be lower than in NVZs, and N is usually applied. In LFAs, we expect a lower level of improvement because there is less application of N (often little or no inorganic N is applied and much of the grassland is grazed with little spreading of manure from housed livestock). Alongside the uptake factor we have an abatement potential range that is very wide (1% to 10% of N_2O emissions from managed soils) reflecting small abatement potential in NVZs and larger potential in non-NVZs.	Medium

Mitigation action (uptake values, %)	Rationale for expert judgement of uptake values in Table 55	Confidence rating
Use of nitrification inhibitors (70%)	One value is provided for all MSs as, if N fertilizers are made available that include nitrification inhibitors, and the action is supported under the CAP, then most (if not all) N fertilizer could be applied with a nitrification inhibitor.	Medium
Improved nitrogen efficiency (100%)	Uptake factor is set at 100% for all MSs on the basis that improved nitrogen efficiency is possible on all farmed land. This MA is applicable in NVZs, non-NVZ land, and LFAs. In NVZs, soils and nutrients are well managed, but there may be some (small) scope for further improvement. On land that is non-NVZ and non-LFA, we would expect greater scope for improvement because current uptake is judged to be lower than in NVZs, and N is usually applied. In LFAs, we expect a lower level of improvement because there is less application of N (often little or no inorganic N is applied and much of the grassland is grazed with little spreading of manure from housed livestock). Alongside the uptake factor we have an abatement potential range that is very wide (1% to 10% of N_2O emissions from managed soils) reflecting small abatement potential in NVZs and larger potential in non-NVZs.	Medium
Biological N fixation in rotations and in grass mixes (5%)	This is the estimated potential of uptake on arable land. One value is provided for all MSs. It is estimated that a further 5% of the arable and grass areas could be sown with legumes.	Low
Carbon auditing tools (10 to 40%)	The uptake factor can be varied according to MS on the grounds that the expertise needed to create the tools, and to assist farmers in the completion of the carbon audits, will not be equally available amongst MSs. The MSs have been organised into four groups based on expert judgement, with a possible uptake value allocated to each group. This categorisation is based on the likely availability of C audit tools and supporting services.	Low

Mitigation action (uptake values, %)	Rationale for expert judgement of uptake values in Table 55	Confidence rating
Improved on-farm energy efficiency (30 to 50%)	This option is likely to have greater long-term potential in MSs with less well developed agricultural systems. In countries with more technical and mechanically advanced systems, there is more likely to be significant adoption of measures to increase energy efficiency, especially more fuel efficient (but more expensive) machinery. However, in the relatively near future the capital costs may limit purchase of newer machinery in many MSs. The Farm Energy MACC project by Ricardo Energy & Environment (previously AEA) estimated uptake of this measure in the UK at 25% in 2015 and 75% by 2030. The values provided are based on our estimate of an additional 50% uptake in the UK by 2030.	Medium

The uptake values are presented in Table 55, with colouring of table cells to emphasise differences between MAs and MSs. The colour key is as follows:

Limited uptake	1 to 4%	(white)
Medium	5 to 19%	(light orange)
Widespread uptake	20 to 100%	(dark orange)

Table 55: Estimated uptake (expert judgement) of MAs, that is additional to current uptake (which in most cases is not known) as a percentage of either the applicable land area, or the applicable number of livestock

MS	Conversion of arable land to grassland to sequester carbon in the soil	New agroforestry	Wetland/peatland conservation/ restoration	Woodland planting	Preventing deforestation and removal of farmland trees	Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land
AT	1%	1%	1%	1%	1%	10%
BE	1%	1%	1%	1%	1%	10%
BG	1%	1%	1%	1%	1%	10%
CY	1%	1%	1%	1%	1%	10%
CZ	1%	1%	1%	1%	1%	10%
DE	1%	1%	1%	1%	1%	10%
DK	1%	1%	1%	1%	1%	10%
EE	1%	1%	1%	1%	1%	10%
EL	1%	1%	1%	1%	1%	10%
ES	1%	1%	1%	1%	1%	10%
FI	1%	1%	1%	1%	1%	10%
FR	1%	1%	1%	1%	1%	10%
HR	1%	1%	1%	1%	1%	10%
HU	1%	1%	1%	1%	1%	10%
IE	1%	1%	1%	1%	1%	10%
IT	1%	1%	1%	1%	1%	10%
LT	1%	1%	1%	1%	1%	10%
LU	1%	1%	1%	1%	1%	10%
LV	1%	1%	1%	1%	1%	10%
MT	1%	1%	1%	1%	1%	10%
NL	1%	1%	1%	1%	1%	10%
PL	1%	1%	1%	1%	1%	10%
PT	1%	1%	1%	1%	1%	10%
RO	1%	1%	1%	1%	1%	10%
SE	1%	1%	1%	1%	1%	10%
SI	1%	1%	1%	1%	1%	10%
SK	1%	1%	1%	1%	1%	10%
UK	1%	1%	1%	1%	1%	10%

Table 55 (continued): Estimated uptake (expert judgement) of MAs, that is additional to current uptake (which in most cases is not known) as a percentage of either the applicable land area, or the applicable number of livestock

MS	Reduced tillage	Zero tillage	Leaving crop residues on the soil surface	Ceasing to burn crop residues and vegetation	Use cover/catch crops	Livestock disease management
AT	5%	5%	1%	100%	10%	55%
BE	5%	5%	1%	100%	10%	50%
BG	5%	5%	1%	100%	10%	40%
CY	5%	5-10%	1%	100%	10%	40%
CZ	5%	5%	1%	100%	10%	45%
DE	5%	5%	1%	100%	10%	55%
DK	5%	5%	1%	100%	10%	55%
EE	5%	5%	1%	100%	10%	45%
EL	5%	5-10%	1%	100%	10%	40%
ES	5%	5-10%	1%	100%	10%	50%
FI	5%	5%	1%	100%	10%	55%
FR	5%	5%	1%	100%	10%	55%
HR	5%	5%	1%	100%	10%	40%
HU	5%	5%	1%	100%	10%	45%
IE	5%	5%	1%	100%	10%	50%
IT	5%	5%	1%	100%	10%	50%
LT	5%	5%	1%	100%	10%	40%
LU	5%	5%	1%	100%	10%	50%
LV	5%	5%	1%	100%	10%	40%
MT	5%	5%	1%	100%	10%	40%
NL	5%	5%	1%	100%	10%	55%
PL	5%	5%	1%	100%	10%	45%
PT	5%	5-10%	1%	100%	10%	45%
RO	5%	5%	1%	100%	10%	40%
SE	5%	5%	1%	100%	10%	55%
SI	5%	5%	1%	100%	10%	45%
SK	5%	5%	1%	100%	10%	45%
UK	5%	5%	1%	100%	10%	55%

Table 55 (continued): Estimated uptake (expert judgement) of MAs, that is additional to current uptake (which in most cases is not known) as a percentage of either the applicable land area, or the applicable number of livestock

MS	Use of sexed semen for breeding dairy replacements	Breeding lower methane emissions in ruminants	Feed additives for ruminant diets	Optimised feeding strategies for livestock	Soil and nutrient management plans	Use of nitrification inhibitors
AT	50%	5%	35%	30%	100%	70%
BE	30%	3%	25%	40%	100%	70%
BG	5%	0%	10%	60%	100%	70%
CY	5%	0%	10%	60%	100%	70%
CZ	15%	1%	15%	50%	100%	70%
DE	50%	5%	35%	30%	100%	70%
DK	50%	5%	35%	30%	100%	70%
EE	15%	1%	15%	50%	100%	70%
EL	5%	0%	10%	60%	100%	70%
ES	30%	3%	25%	40%	100%	70%
FI	50%	5%	35%	30%	100%	70%
FR	50%	5%	35%	30%	100%	70%
HR	5%	0%	10%	60%	100%	70%
HU	15%	1%	15%	50%	100%	70%
IE	30%	3%	25%	40%	100%	70%
IT	30%	3%	25%	40%	100%	70%
LT	5%	0%	10%	60%	100%	70%
LU	30%	3%	25%	40%	100%	70%
LV	5%	0%	10%	60%	100%	70%
MT	5%	0%	10%	60%	100%	70%
NL	50%	5%	35%	30%	100%	70%
PL	15%	1%	15%	50%	100%	70%
PT	15%	1%	15%	50%	100%	70%
RO	5%	0%	10%	60%	100%	70%
SE	50%	5%	35%	30%	100%	70%
SI	15%	1%	15%	50%	100%	70%
SK	15%	1%	15%	50%	100%	70%
UK	50%	5%	35%	30%	100%	70%

Table 55 (continued): Estimated uptake (expert judgement) of MAs, that is additional to current uptake (which in most cases is not known) as a percentage of either the applicable land area, or the applicable number of livestock

MS	Improved nitrogen efficiency	Biological N fixation in rotations and in grass mixes	Carbon auditing tools	Improved on-farm energy efficiency
AT	100%	5%	40%	50%
BE	100%	5%	30%	45%
BG	100%	5%	10%	30%
CY	100%	5%	10%	30%
CZ	100%	5%	20%	35%
DE	100%	5%	40%	50%
DK	100%	5%	40%	50%
EE	100%	5%	20%	35%
EL	100%	5%	10%	30%
ES	100%	5%	30%	45%
FI	100%	5%	40%	50%
FR	100%	5%	40%	50%
HR	100%	5%	10%	30%
HU	100%	5%	20%	35%
IE	100%	5%	30%	45%
IT	100%	5%	30%	45%
LT	100%	5%	10%	30%
LU	100%	5%	30%	45%
LV	100%	5%	10%	30%
MT	100%	5%	10%	30%
NL	100%	5%	40%	50%
PL	100%	5%	20%	35%
PT	100%	5%	20%	35%
RO	100%	5%	10%	30%
SE	100%	5%	40%	50%
SI	100%	5%	20%	35%
SK	100%	5%	20%	35%
UK	100%	5%	40%	50%

Estimated mitigation potential

Mitigation potential was estimated as described in section 4.1, and values (high, low and median) are presented in Table 56, for each MA and MS. Values are presented to two significant figures (following convention for carbon footprint reporting), allowing presentation of values that differ by many orders of magnitude without implying excessive accuracy.

The mitigation potential values for different MAs cannot be added to gain an estimate of the total potential, because many MAs mitigate the same categories of GHG emissions, and some are mutually exclusive on the same area of land. Furthermore, some MAs (Carbon auditing tools and Soil and nutrient management plans) are actions to plan and implement other mitigation actions. See section 4.2 for more details of interactions between MAs.

Colouring of table cells is used to emphasise differences between MAs and MSs. The colour key is as follows:

< 10	
10 to 99	
100 to 999	
1,000 to 10,000	
> 10,000	

Table 56: Low high and median mitigation potential values (kt CO_2e/y) for each mitigation action and each Member State, given to two significant figures

	Conversion of arable land to grassland to sequester carbon in the soil			New agroforestry			Wetland/peatland conservation/restoration			Woodland planting			Preventing deforestation and removal of farmland trees			Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land			Reduced tillage		
MS	**Low**	**High**	**Median**	**Low**	**High**	**Median**	**Low**	**High**	**Median**	**Low**	**High**	**Median**	**Low**	**High**	**Median**	**Low**	**High**	**Median**	**Low**	**High**	**Median**
AT	32	110	69	4.6	28	16	0.00074	0.0046	0.0027	46	58	52	28	280	150	140	140	140	1.3	3.9	2.6
BE	20	66	43	2.1	12	7.3	0.00056	0.0035	0.002	21	26	23	4.3	43	24	22	22	22	0.8	2.4	1.6
BG	74	250	160	7.7	46	27	0	0	0	77	97	87	26	260	140	130	130	130	3	9.1	6
CY	3.4	11	7.5	0.25	1.5	0.87	0	0	0	2.5	3.1	2.8	1.3	13	7.2	6.5	6.5	6.5	0.14	0.42	0.28
CZ	66	220	140	6	36	21	0.0013	0.0085	0.0049	60	75	67	20	200	110	98	98	98	2.7	8.1	5.4
DE	330	1100	590	29	180	88	0.017	0.11	0.063	290	370	280	83	830	440	420	420	400	13	40	22
DK	55	180	120	4	24	14	0.00043	0.0027	0.0016	40	50	45	3.6	36	20	18	18	18	2.2	6.7	4.5
EE	13	43	28	1.2	7.3	4.3	0.05	0.32	0.18	12	15	14	17	170	91	83	83	83	0.52	1.6	1
EL	72	240	160	6.4	38	22	0	0	0	64	80	72	27	270	150	130	130	130	2.9	8.8	5.9
ES	390	1300	840	38	230	130	0.00066	0.0042	0.0024	380	480	430	110	1100	580	530	530	530	16	47	31
FI	51	170	110	3.5	21	12	0.89	5.6	3.2	35	44	39	160	1600	900	820	820	820	2.1	6.3	4.2
FR	440	1500	960	43	260	150	0.0017	0.011	0.0062	430	540	490	110	1100	620	570	570	570	18	54	36
HR	22	73	48	2	12	6.9	0	0	0	20	25	22	16	160	86	78	78	78	0.9	2.7	1.8
HU	110	350	230	8.5	51	30	0.000017	0.00011	0.000063	85	110	96	14	140	78	70	70	70	4.3	13	8.6
IE	23	76	49	6.3	38	22	0.059	0.37	0.22	63	79	71	4.8	48	26	24	24	24	0.93	2.8	1.9
IT	220	750	490	21	120	73	0.0000036	0.000023	0.000013	210	260	230	71	710	390	360	360	360	9.1	27	18
LT	44	150	96	4.4	26	15	0.0056	0.035	0.02	44	55	49	15	150	85	77	77	77	1.8	5.4	3.6
LU	1.4	4.6	3	0.18	1.1	0.62	0	0	0	1.8	2.2	2	0.57	5.7	3.1	2.8	2.8	2.8	0.056	0.17	0.11
LV	27	89	58	2.8	17	9.9	0.024	0.15	0.088	28	35	32	22	220	120	110	110	110	1.1	3.3	2.2
MT	0.21	0.7	0.46	0.015	0.093	0.054	0	0	0	0.15	0.19	0.17	0.0063	0.063	0.035	0.032	0.032	0.032	0.0086	0.026	0.017
NL	24	81	52	2.9	17	10	0.0012	0.0073	0.0042	29	36	32	2.7	27	15	13	13	13	0.98	3	2
PL	300	1000	650	25	150	88	0.0021	0.013	0.0078	250	310	280	68	680	370	340	340	340	12	37	24
PT	46	150	100	4.8	29	17	0	0	0	48	60	54	26	260	140	130	130	130	1.9	5.7	3.8
RO	210	690	450	21	120	72	0.0002	0.0013	0.00073	210	260	230	47	470	260	230	230	230	8.4	25	17
SE	58	190	130	4.6	27	16	0.6	3.8	2.2	46	57	51	200	2000	1100	1000	1000	1000	2.4	7.1	4.8
SI	4.8	16	10	0.75	4.5	2.6	0	0	0	7.5	9.3	8.4	9.2	92	51	46	46	46	0.19	0.58	0.39
SK	33	110	71	3.2	19	11	0.0000099	0.000062	0.000036	32	40	36	14	140	79	71	71	71	1.3	4	2.7
UK	130	450	290	23	140	82	0.29	1.9	1.1	230	290	260	21	210	110	100	100	100	5.5	16	11
EU	**2800**	**9300**	**5900**	**280**	**1700**	**950**	**1.9**	**12**	**7.1**	**2800**	**3500**	**3100**	**1100**	**11000**	**6200**	**5600**	**5600**	**5600**	**110**	**340**	**220**

	Zero tillage			Leaving crop residues on the soil surface			Ceasing to burn crop residues and vegetation			Use cover/catch crops			Livestock disease management			Use of sexed semen for breeding dairy replacements			Breeding lower methane emissions in ruminants		
MS	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
AT	2.6	7.8	5.2	1.6	32	17	N/A	N/A	0.62	130	210	170	24	240	130	16	56	36	0.76	1.5	1.1
BE	1.6	4.8	3.2	0.98	20	10	N/A	N/A	0	79	130	100	29	290	160	11	38	24	0.5	1	0.75
BG	6	18	12	3.7	74	39	N/A	N/A	34	300	490	400	9.5	95	52	0.48	1.7	1.1	0	0	0
CY	9.2	28	19	0.17	3.4	1.8	N/A	N/A	0.7	14	23	18	1.8	18	10	0.052	0.18	0.12	0	0	0
CZ	5.4	16	11	3.3	66	35	N/A	N/A	0	260	440	350	14	140	78	3.4	12	7.6	0.098	0.2	0.15
DE	27	81	45	16	330	140	N/A	N/A	0	1300	2200	1500	160	1600	860	110	400	260	5	10	7.5
DK	4.5	13	9	2.8	55	29	N/A	N/A	3.4	220	370	290	25	250	140	16	55	35	0.64	1.3	0.95
EE	1	3.1	2.1	0.64	13	6.7	N/A	N/A	0	51	85	68	2.6	26	14	0.64	2.2	1.4	0.021	0.041	0.031
EL	46	140	93	3.6	72	38	N/A	N/A	44	290	480	390	16	160	91	0.45	1.6	1	0	0	0
ES	520	1600	1100	19	390	200	N/A	N/A	520	1500	2600	2100	94	940	510	23	82	53	1.4	2.8	2.1
FI	4.2	13	8.4	2.6	51	27	N/A	N/A	0.51	210	340	270	12	120	67	4.3	15	9.7	0.2	0.4	0.3
FR	36	110	72	22	440	230	N/A	N/A	32	1800	2900	2400	240	2400	1300	160	550	350	6.9	14	10
HR	1.8	5.4	3.6	1.1	22	12	N/A	N/A	0	88	150	120	5.3	53	29	0.37	1.3	0.84	0	0	0
HU	8.6	26	17	5.3	110	56	N/A	N/A	0	420	700	560	16	160	89	2.5	8.8	5.7	0.068	0.14	0.1
IE	1.9	5.6	3.7	1.1	23	12	N/A	N/A	0	91	150	120	58	580	320	29	100	66	1.3	2.6	2
IT	18	55	37	11	220	120	N/A	N/A	19	900	1500	1200	86	860	470	29	100	65	1.5	3.1	2.3
LT	3.6	11	7.2	2.2	44	23	N/A	N/A	0	180	300	240	7.8	78	43	0.69	2.4	1.6	0	0	0
LU	0.11	0.34	0.23	0.069	1.4	0.73	N/A	N/A	0	5.5	9.2	7.4	1.8	18	10	0.86	3	1.9	0.035	0.07	0.053
LV	2.2	6.5	4.3	1.3	27	14	N/A	N/A	0	110	180	140	3.6	36	20	0.36	1.3	0.8	0	0	0
MT	0.017	0.052	0.034	0.011	0.21	0.11	N/A	N/A	0	0.84	1.4	1.1	0.22	2.2	1.2	0.016	0.057	0.036	0	0	0
NL	2	5.9	3.9	1.2	24	13	N/A	N/A	0	97	160	130	56	560	310	38	130	85	1.5	3	2.3
PL	24	73	49	15	300	160	N/A	N/A	30	1200	2000	1600	73	730	400	14	49	32	0.43	0.85	0.64
PT	57	180	120	2.3	46	24	N/A	N/A	43	190	310	250	18	180	100	3.4	12	7.5	0.13	0.26	0.2
RO	17	51	34	10	210	110	N/A	N/A	110	830	1400	1100	39	390	220	1.7	5.8	3.7	0	0	0
SE	4.8	14	9.5	2.9	58	31	N/A	N/A	43	230	390	310	18	180	100	12	42	27	0.56	1.1	0.84
SI	0.39	1.2	0.78	0.24	4.8	2.5	N/A	N/A	0	19	32	25	5.3	53	29	1.4	4.7	3.1	0.032	0.063	0.047
SK	2.7	8	5.3	1.6	33	17	N/A	N/A	0	130	220	170	6.4	64	35	1.3	4.5	2.9	0.043	0.086	0.064
UK	11	33	22	6.7	130	71	N/A	N/A	0	540	900	720	140	1400	750	79	270	180	3.7	7.5	5.6
EU	**820**	**2500**	**1700**	**140**	**2800**	**1400**	**N/A**	**N/A**	**880**	**11000**	**19000**	**15000**	**1200**	**12000**	**6400**	**560**	**2000**	**1300**	**25**	**50**	**37**

	Feed additives for ruminant diets			Optimised feeding strategies for livestock			Soil and nutrient management plans			Use of nitrification inhibitors			Improved nitrogen efficiency			Biological N fixation in rotations and in grass mixes			Carbon auditing tools			Improved on-farm energy efficiency		
MS	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median	Low	High	Median
AT	28	56	42	6.9	21	14	31	310	170	470	1400	930	31	310	170	92	180	140	300	600	450	40	79	60
BE	22	45	33	7.7	23	15	35	350	190	440	1300	870	35	350	190	110	210	160	280	560	420	95	190	140
BG	3.2	6.4	4.8	8.9	27	18	40	400	220	590	1800	1200	40	400	220	120	240	180	65	130	98	15	29	22
CY	0.48	0.97	0.73	2.3	6.9	4.6	3.5	35	19	56	170	110	3.5	35	19	11	21	16	8.2	16	12	2.4	4.8	3.6
CZ	7.6	15	11	8.3	25	17	49	490	270	730	2200	1500	49	490	270	150	290	220	160	320	240	6.6	13	10
DE	180	360	270	21	63	42	410	4100	2300	6200	19000	12000	410	4100	2300	1200	2500	1800	2800	5600	4200	310	620	460
DK	25	51	38	2.9	8.8	5.9	50	500	280	750	2300	1500	50	500	280	150	300	230	380	770	580	100	210	160
EE	1.6	3.2	2.4	1.3	4	2.7	7.5	75	41	110	320	210	7.5	75	41	22	45	34	27	53	40	8.8	18	13
EL	7.8	16	12	8.9	27	18	48	480	260	520	1600	1000	48	480	260	140	290	220	91	180	140	26	52	39
ES	64	130	96	15	46	30	180	1800	1000	2400	7200	4800	180	1800	1000	540	1100	820	1100	2300	1700	490	980	730
FI	14	27	20	3.1	9.4	6.2	35	350	190	520	1600	1000	35	350	190	100	210	160	230	460	340	76	150	110
FR	250	490	370	37	110	75	460	4600	2500	5900	18000	12000	460	4600	2500	1400	2800	2100	3600	7100	5400	570	1100	850
HR	2.1	4.2	3.1	4.4	13	8.7	21	210	110	300	900	600	21	210	110	62	120	93	34	68	51	20	40	30
HU	5.6	11	8.5	11	32	21	51	510	280	770	2300	1500	51	510	280	150	310	230	170	350	260	30	61	45
IE	55	110	83	4.6	14	9.3	65	650	350	590	1800	1200	65	650	350	190	390	290	540	1100	810	31	62	47
IT	67	130	100	35	110	70	170	1700	910	2400	7200	4800	170	1700	910	500	1000	750	1100	2100	1600	310	610	460
LT	3	5.9	4.4	3.9	12	7.9	31	310	170	460	1400	920	31	310	170	93	190	140	51	100	76	3	6	4.5
LU	1.5	3	2.2	0.33	0.98	0.65	3	30	17	39	120	78	3	30	17	9.1	18	14	20	40	30	2.3	4.6	3.4
LV	1.7	3.4	2.6	1.8	5.5	3.7	15	150	83	220	670	450	15	150	83	45	91	68	24	48	36	11	22	17
MT	0.072	0.14	0.11	0.056	0.17	0.11	0.25	2.5	1.4	4	12	8	0.25	2.5	1.4	0.76	1.5	1.1	0.79	1.6	1.2	0.68	1.4	1
NL	57	110	86	7.6	23	15	57	570	310	730	2200	1500	57	570	310	170	340	260	640	1300	950	460	920	690
PL	34	67	50	61	180	120	200	2000	1100	3100	9400	6300	200	2000	1100	610	1200	910	730	1500	1100	360	720	540
PT	10	20	15	3.7	11	7.3	29	290	160	340	1000	670	29	290	160	88	180	130	140	290	220	36	71	53
RO	20	40	30	18	55	36	83	830	460	1200	3500	2300	83	830	460	250	500	370	180	360	270	35	69	52
SE	22	44	33	3.3	9.9	6.6	43	430	240	510	1500	1000	43	430	240	130	260	200	310	610	460	74	150	110
SI	2.4	4.9	3.7	1.7	5.1	3.4	6.9	69	38	100	300	200	6.9	69	38	21	42	31	37	75	56	7.3	15	11
SK	3.3	6.6	5	4.7	14	9.5	18	180	100	280	830	550	18	180	100	55	110	83	65	130	98	3.1	6.1	4.6
UK	140	270	200	20	60	40	270	2700	1500	3300	9900	6600	270	2700	1500	810	1600	1200	2100	4100	3100	210	420	310
EU	**1000**	**2000**	**1500**	**300**	**910**	**610**	**2400**	**24000**	**13000**	**33000**	**99000**	**66000**	**2400**	**24000**	**13000**	**7200**	**14000**	**11000**	**15000**	**30000**	**23000**	**3300**	**6700**	**5000**

The estimated mitigation potential values above are given by MS, and are influenced by the size (area) of the MSs through the variation in the area of land, or number of livestock that the MAs are applicable to. A consequence of this is that MSs with a large land area, and especially those with a large area in agricultural production (e.g. France, Germany) generally have higher values that MSs with a small area in agricultural production (e.g. Malta).

Mitigation potential values are greatest for use of nitrification inhibitors, and are also high for other MAs that relate to use of N fertilizers (e.g. improved N efficiency).

Another MA for crop production systems and with high mitigation potential values, is use of cover/catch crops; this MA also interacts with use of N fertilizer and emission of N_2O from soil.

For livestock systems, MAs generally have relatively low mitigation potential, with the exception of livestock disease management.

Some of the MAs that involve land use change or its prevention have high mitigation potential (e.g. conversion of arable land to grassland, preventing deforestation and removal of farmland trees).

Overview of mitigation actions by Member State

Mitigation actions are presented in chapter 3 with a sub-section for each action, and the information presented includes mitigation potential, geographic relevance (using maps), and national reporting of the emissions mitigated. To supplement that output and the mitigation potential estimates in the tables above, we provide a summary table (in Annex 3) to summarise information by MS. Because of the large body of information assembled in this project, it is not possible to present all the detail of the analysis in the Annex, but further detail is available in other chapters of this report. In Annex 3 we present, for each of the 28 MSs, the information that is listed in the first column of in Table 57, which also gives locations of further details and notes on the information presented.

Table 57: information presented in Annex 3, locations of further detail, and notes

Information presented		Location of further detail	Notes
Mitigation actions (MA)		Chapter 3	
Mitigation potential	Using 1% of possible MA uptake	For information source and values: Chapter 3; For calculated values by MS, section 4.3, Table 53	Units are t/ha/year CO_2e. Median values are presented, but ranges (high, low, median) are given elsewhere. Values are presented to two significant figures (following convention for carbon footprint reporting), allowing presentation of values that differ by many orders of magnitude without implying excessive accuracy.
	Using expert judgement to estimate MA uptake	For calculated values by MS, section 4.4, Table 56.	
Applicability		Values not given elsewhere, but see geographic relevance maps in Chapter 3.	E.g. area of land or number of livestock. Units vary and are given with each value.

Information presented			Location of further detail	Notes
Implementation	Farm-level barriers/ opportunities		Chapter 6	
	Relevant CAP measures		Chapter 3	Where it is appropriate to promote this climate mitigation action
IPCC Accounting	Main IPCC (1996) Category Impacted		Chapter 3	Refers to the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Some MAs mitigate GHG emissions in multiple categories; see previous column of this table for further details.
	Identified as a Key Category in 2012 NIRs		Chapter 3	Information given as Yes or No. NIRs for emissions in 2012 were submitted in 2014 and were the most recent available at the time of this work.
	Ability to account	Current tier used	Chapter 3	In 2014 NIR submissions, for emissions in 2012
		Ability to demonstrate mitigation in the inventory	Chapter 3	For each MA, this is the ability of the NIRs to demonstrate that any mitigation was linked to the MA
	Limitations for accounting		Chapter 3	E.g. limitations may relate to methodology available, the ability to implement methods at the necessary Tier, or availability of activity data.
Timescales	Timescale for implementation by land manager		Chapter 3, subsections headed “Costs/business benefits to land managers of implementing the MA at farm/forest level”	
	Timescale of mitigation effect		Not given elsewhere	

5 Additional administrative effort required to implement climate mitigation actions

5.1 Introduction

This section looks at the question of how feasible it is likely to be for Member States to implement the chosen mitigation actions in practice, focussing specifically on any additional administrative efforts that may be required. It considers the likely nature and scale of those additional administrative efforts that may be necessary for Member States to make in order a) to widen the implementation of climate mitigation actions they are already using or b) to introduce new climate mitigation actions under different CAP policy mechanisms in the areas in which they are a priority.

For a number of climate mitigation actions, there is a need for additional efforts to improve the level of accuracy with which the emissions concerned are reported in the National Inventory Reports (NIRs). Indeed, the extent to which such emissions are 'visible' in the NIRs will have some bearing on whether or not a climate mitigation action is prioritised for implementation (see the following section on barriers). However, the costs for improving reporting methods and data already fall under the requirements of existing legislation[38] and therefore fall outside the scope of this chapter. Nonetheless, it should be noted that farm level data collected under the CAP (e.g. via the IACS system) is an important resource to be used by Member States for their GHG emission/ LULUCF reporting and accounting.

The additional costs to farm businesses of implementing individual climate mitigation actions are also relevant and are considered, by measure in Section 3 (Analysis of mitigation actions).

5.2 The baseline

The baseline against which potential additional administrative efforts and costs arising for public authorities are assessed is the current level of administrative costs imposed by the CAP regulations. These costs stem from the current arrangements in place for the implementation of CAP for the current period, 2014 to 2020, including all those costs related to the design, implementation, control and monitoring and evaluation of:

- Cross-compliance;
- Payments for agricultural practices beneficial for the climate and the environment ('green direct payments' in Pillar One)
- Rural Development Programmes

The administrative efforts/costs (or burden) expected to be associated with this CAP legislation have been set out in a number of documents, most recently in the impact assessments accompanying the proposals for the 2013 CAP reform[39]. The particular costs that are the focus of this part of the study are the additional costs potentially incurred by public administrations in the course of implementing, via the CAP, climate mitigation actions that have been identified as a relevant in particular regions and Member States in the EU from 2015 onwards.

[38] UNFCCC and Kyoto Protocol requirements; and requirements set out under EU LULUCF Decision (EC 529/2013) and Monitoring Mechanism Regulation (EC 525/2013).
[39] European Commission (2011), COMMISSION STAFF WORKING PAPER IMPACT ASSESSMENT Common Agricultural Policy towards 2020, SEC(2011) 1153

It should be noted that there is no compulsion or formal requirement on Member States to put in place the climate mitigation actions identified through this study. Therefore the costs identified here are provided as an indication of the sort of costs that might be incurred if Member States choose to extend or enhance the implementation of existing climate mitigation actions via the CAP or introduce new climate mitigation actions over time, where these have been identified as being of particular relevance.

5.3 Types of administrative activities considered

Administrative activities which incur costs (often referred to in the literature as ‘policy related transaction costs – PRTCs[40]) occur throughout the various stages of the policy cycle. This includes the preparatory stages of setting objectives, gathering data and designing the measure, through implementation to monitoring and evaluation. The administrations which incur the additional efforts may be central government, regional/local government or other public bodies and agencies. Sometimes the combined efforts of several administrative tiers will be required.

The efforts and associated costs can be one-off (such as setting the rules and targeting for a measure) or recurring costs (such as annual controls and inspections). Although the majority of costs associated with the administrative activities relate to staff time, there may also be other operational costs that are incurred (such as software, office equipment and other materials – including printed guidance documents).

For the purposes of this study, the main area of focus is those additional activities (compared with the baseline) that may be incurred in order to implement the chosen climate mitigation actions under the CAP during the 2014 to 2020 period. The categories of administrative activities that are reviewed here are set out in Table 58. The activities have been divided into five different types categorised under three phases of the policy cycle: preparation (data gathering, assembly and measure design); implementation (measure delivery and compliance control); and monitoring and evaluation.

Table 58: Categories of administrative activities

Phase	Type of activity	Detailed activity
Preparation	Data gathering and assembly	• Establishing the baseline and target levels for emissions – could include commissioning of research projects and / or using in house expertise; agency collaboration
		• Identifying which of the range of CAP measures (or which combination) would be most appropriate for implementing a particular climate mitigation action
	Measure design	• Assessment of cost-effectiveness of action
		• Identification of rules (which may include detailed prescriptions) for the measures to achieve desired outcomes
		• Legal work and consultation, required as a precursor to the introduction of measures
		• Determination of target level or type of uptake/ areas / farming systems/ soil types for measure implementation

[40] See, for example, OECD (2007), The Implementation costs of agriculture policies, OECD, Paris.

		• Identification of control criteria
Implementation	Measure delivery	• Design of application process and costs of staff to process applications and make payments
		• Training costs for staff
		• Development of official guidance for measures
		• Identification of beneficiaries
		• Provision of technical advice, training – on-line, face-to-face, in groups/individually
	Compliance control	• Costs of staff to carry out controls – paper and IT-based checks and in-field inspections;
		• Enforcement and costs of imposing penalties if required
		• Costs of any additional technology or means of controls – remote-sensing etc.
Monitoring and evaluation	Monitoring and evaluation	• Research costs if specific evaluations/assessments need to be commissioned (often contracted out);
		• Identification of suitable indicators
		• Costs to measure the baseline and progress against relevant CAP MEF indicators

5.4 Data availability and issues arising

To calculate the scale of administrative costs that are incurred by public administrations in implementing a particular policy, information is needed on both labour and operational expenditures, with due allowance for overheads. To carry out a thorough exercise, information would be needed on:

- The different types of policy measures operating in a particular country and how they are implemented;
- The various organisations involved in the delivery and control of the policy at all levels of government;
- Budget information on administrative costs for each organisation;
- The structure of each organisation;
- The time spent on tasks and measures by each organisational department;
- The number of staff in each category by department;
- The average salary of each staff category and related overheads;
- Costs of contracted agencies to whom tasks are delegated[41].

However, there is little empirical data available on the scale of the costs for public administrations of the implementation of either agricultural or climate policies (or other environmental policies[42]). Even where studies have been carried out, the information gathered is indicative at best. Often the evidence is anecdotal in nature or based on case study examples in particular Member States and not collected using standard methodologies.

The OECD carried out a literature review of studies on the policy related transaction costs of implementing agricultural policies, focussing on those where quantitative estimates were provided (OECD, 2007). This provides some interesting data and allows for some comparisons between countries of the costs of the implementation of different types of

[41] Adapted from OECD, 2007 *ibid*
[42] Institute for European Environmental Policy, Institute for Environmental Studies, ICF GHK, Naider (2015), Study to analyse differences in costs of implementing EU policy. A project under DG Environment's Framework contract for economic analysis ENV.F.1/FRA/2010/0044

measures (direct payments and more targeted measures, e.g. agri-environment climate measures) to be made. However, the data are not broken down into more detailed categories, such as those reviewed for this study, nor are they broken down by different elements of the schemes reviewed (i.e. by the particular type of management action). They therefore provide only a sense of the scale and variation between member countries of the baseline costs of implementing different types of policy instruments against which the 'additional' costs of extending the use of such measures or introducing new elements to these measures can be assessed. It should be noted that many of the figures in this OECD study are from the mid-1990s and costs are likely to have changed since this time, and probably decreased, since administrative costs tend to reduce as schemes become more mature and experience regarding their management develops.

Administrative costs vary significantly between EU Member States (and even between regions within Member States). Reasons for this include: basic differences in costs (particularly salary costs) and the way they are measured in different parts of the EU; institutional structures (rules governing the public administration in the Member State), the starting point in terms of the capacity of the relevant administrations, the policy choices already made, as well as the scale, distribution and complexity of their implementation choices in relation to the climate mitigation actions

The OECD report provides some reasons for why such costs can vary significantly for similar types of measure both between regions and countries. It suggests that this 'may reflect structural characteristics of the sector (e.g. dominance of small farms with high fixed costs per payment), differences in implementation and control conditions, (e.g. different conditions, more stringent or frequent checks on compliance) or simply differences in administrative efficiency'[43]. In general targeted measures have higher administrative costs than broad brush measures. These considerations seem highly likely to apply in the EU.

Drawn from OECD work and other literature examples of some of administrative costs that have been identified for authorities implementing CAP measures in different Member States are included in Box 5. These costs help to provide an indication of the scale of the baseline costs against which any additional costs associated with extending or introducing climate mitigation actions into the CAP can be assessed.

Box 5: Examples of administrative costs associated with CAP measures in different EU Member States

The following figures show the differing policy related transaction costs of agri-environment programmes (with varying objectives, design, coverage, uptake and levels of maturity) in a range of EU Member States in the mid-1990s (OECD, 2007). Costs will have changed significantly since this date not least because the schemes in question have evolved, but they serve to illustrate the variation in administrative costs between countries for agri-environment schemes, due to the different ways in which schemes are designed and implemented as well as difference in the costs of labour and institutional factors. Such variations are likely to continue to apply although the costs in question will have changed.

Country	Year	PRTCs in EUR/ha	PRTCs in EUR/participant
Austria	1996/97	20.5	217
Belgium	1996	59	389
France	1996	76	1,522
Germany	1994/95	10	177
Greece	1996/97	60	470
Italy		13	140

[43] OECD, 2007 ibid

Sweden	1995	9	190
UK	1996/97	48	2,446

N.B. PRTCs are policy related transaction costs.

Another illustration of the variation is visible in the differing PRTCs for aid schemes for organic farming in five EU countries. Again, data is from the 1990s and therefore no longer accurate but it shows both the range and how costs can differ depending on the scale of a scheme (source OECD, quoting Falconer and Whitby, 1999).

Country	Year	Hectares	Number of agreements	Annual PRTCs (Eur/ha)	Annual PRTCs (EUR/agreement	Overall PRTCs (EUR)[1]
Austria	1997	280,000	20,000	1.4	19.0	380,000
Belgium	1996	3,591	143	5.8	146.3	21,000
England	1996	7,875	170	30.7	1,242.0	242,000
France	1996	32,332	1,417	55.9	1,275.4	1,800,000
Greece	1997	4,000	837	119.8	572.5	479,000

[1] own calculations, not included in the original publication

To show how PRTCs can decrease over time, particularly over the lifetime of a measure, a National Audit Office report into the organic element of England's agri-environment scheme (NAO, 2010[44]) estimated that processing the scheme cost an average of £637 per claim in 2008-09, of which 84 per cent related to IT costs. This is considerably lower than the estimate for 1996. This was compared to the costs of administering the CAP single payment scheme (SPs) in 2008-09 – the processing cost per claimant for the SPS was calculated to be £1,743 per claim, although it is not clear what costs have been included within this calculation (approximately €2,090).

Some cost information is also available for a few countries in relation to cross-compliance. For example, a study on the costs of cross-compliance in England (ADAS, 2009[45]) estimated the public costs of the environmental elements of cross-compliance on farms to be in the region of £8.3 million/year (approximately €9.9 million). This covers policy costs, support costs (for information, training) and inspection costs. A study by the Swedish Board of Agriculture (Jordbruksverket, 2011[46]) calculated that the overall administrative cost of implementing cross compliance in Sweden was in the region of SEK 12 million per year (approximately €1.3 million). This was broken down into SEK 6 million for inspections and a further SEK 6 million for central administration costs.

In relation to the Farm Advisory System (FAS), a project by Berglund *et al.,* (2010)[47] studied the costs of the FAS at pan-European level in relation to advice on water. This project provides quantified estimates of the cost of providing farm advice on water issues in Sweden and England. In England this advice was provided under the England Catchment Sensitive Farming Delivery Initiative (ECSFDI) which specifically targeted diffuse water pollution from agriculture. At the time of the report, £2 (€2.5) million/year was allocated to contractors to provide advice and £1.2 (€1.5) million/year paid for 50 FTE adviser posts. The costs for one advice visit were averaged at £600 (€750) and the costs of a training workshop were estimated to be in the region of £1,500 (€1,875). In Sweden, advice was designed rather differently. However, total costs for the advice service to farmers were estimated to be in the region of €2.2 million in 2009.

[44] National Audit Office (2010) Defra's Organic agri-environment scheme, Report by the Comptroller and Auditor General, HC 513, Session 2009–2010, 31 March 2010
[45] Defra (2011) Evaluation of Cross Compliance. Presentation at OECD workshop in Braunschweig. Summary of evaluation by ADAS (2009).
[46] Jordbruksverket (2011) Environmental Effects of Cross-Compliance. Swedish Board of Agriculture.
[47] Berglund, M.; Dworak, T. (2010): *Integrating water issues in Farm advisory services - A Handbook of ideas for administrations.* Ecologic Institute.

5.5 Assessment of additional administrative effort by type of CAP instrument

In the relation to the CAP, the additional administrative efforts required for running the mitigation actions have been assessed according to two different situations:

i. Where the climate mitigation action in question is already implemented in some areas of the country via the CAP and the new step is its implementation being extended to other areas or its level of uptake is increased within existing target areas ('more of the same');

ii. where the climate mitigation action is not currently implemented via the CAP in the Member State concerned and is introduced, either by:
   a. amending the way in which an existing CAP measure is implemented (e.g. changing GAEC definitions, permitting additional elements within EFAs, amending the agri-environment-climate measure), or
   b. by introducing a new CAP measure that has hitherto not been used (e.g. the agroforestry measure or aid for non-productive investments, if not previously used).

These two situations are considered against the current 2014 to 2020 CAP implementation framework. (No assessments are carried out against possible future revisions to this framework, given that any such assessment would depend upon what requirements any future CAP legislation places on Member States).

In terms of implementing the currently selected measures in the current version of the CAP, including the most significant costs, both the set up and running costs, are already part of the baseline. In addition there are no new legislative requirements being imposed on Member States for climate purposes. Rather the additional efforts being considered here are those that 'may' be adopted by Member States should they decide to extend the use of or introduce the climate mitigation actions on their agricultural or forest land via the CAP in the period 2014 to 2020.

In addition, it should be noted that additional administrative effort has been calculated for each individual climate mitigation action. Such actions may constitute only a small element of a full RDP scheme, such as an agri-environment-climate scheme. For example, in England the agri-environment-climate scheme (Countryside Stewardship) consists of around 250 different management options, of which a single climate mitigation action would be just one. The costs relating to a single climate mitigation action therefore generally, will be a very small proportion of the administrative effort for the scheme as a whole.

The additional administrative effort required has been assessed against the baseline set out above and is assessed at the level of a Member State or region in the case of RDPs (using average cost figures) for each climate mitigation action. To assess the overall potential additional administrative effort that Member States may incur in extending or introducing certain climate mitigation actions, one would need to multiply the costs for all relevant cost categories for the relevant climate mitigation action by the number of Member States and/or regions choosing to implement it. They may do this through cross-compliance, Pillar 1 of the CAP and/or their RDPs. Since not all climate mitigation actions are relevant in all parts of all Member States, a simple multiplication of the estimated costs in one region by 28 or 118 (in the case of RDPs) would give a significant overestimation of additional efforts/costs involved. It is for this reason that this calculation has not been made here.

As explained in the data section above, it is not possible to provide accurate figures on the likely additional administrative effort entailed in extending the use of existing climate mitigation actions or introducing new climate mitigation actions into the CAP. Nonetheless, in order to provide a sense of the scale of additional efforts that may be required, the different categories of action have been assessed against five bands of costs as set out in Table 59. The bands consist of a range expressed in both euros and in person months (using an average monthly cost per person). Each climate mitigation action has been allocated to one of these bands based on expert judgement[48]. Costs are also identified in terms of whether they are likely to be a 'one-off' cost or a recurring cost.

The average monthly staff costs for administrations were calculated on the basis of the average hourly labour cost in the EU-28 (estimated to be €24.60 in 2014 (Eurostat[49]), although this average clearly masks significant different between EU Member States with hourly labour costs ranging between €3.80 to €40.30 – see Table 60). The average figure was then extrapolated to an average monthly labour cost of €4,400 (hourly labour cost x 8 (hours per day) x 22 (days per month)). To assess the potential costs for individual Member States the scale of costs identified in Table 59 would need to be adjusted to reflect the average monthly labour cost for each Member State, as set out in Table 60.

Table 59: Scale used to assess administrative costs associated with extending or introducing climate mitigation actions in Member States

-	No additional costs
1	< €10,000 / ~ 2 person months
2	€10,001-€25,000 / ~2-6 person months
3	€25,001-€50,000 / ~6-12 person months
4	€50,001- €100,000 / ~12-24 person months
5	> €100,000 / > ~24 person months

Table 60: Average monthly staff costs for individual Member States

	Estimated hourly labour costs, 2014	Estimated monthly labour costs
European Union (28 countries)	24.6	4,330
Belgium	39.0	6,864
Bulgaria	3.8	669
Czech Republic	9.4	1,654
Denmark	40.3	7,093
Germany	31.4	5,526
Estonia	9.8	1,725
Ireland	29.8	5,245
Greece	14.6	2,570
Spain	21.3	3,749
France	34.6	6,090
Croatia	9.4	1,654
Italy	28.3	4,981
Cyprus	15.8	2,781
Latvia	6.6	1,162

[48] Members of the study team have a long experience of working in or with government and its statutory agencies in the UK on the design, implementation and evaluation of various CAP measures. The assessments have been based on these experiences and cross-checked between team members. Given the experience has been in the UK, with a track record of generally thorough implementation of CAP instruments, it can be expected that these estimates are likely to be near the maximum level that would be required.
[49] Eurostat data on 'Wages and Labour costs': http://ec.europa.eu/eurostat/statistics-explained/index.php/Wages_and_labour_costs

Lithuania	6.5	1,144
Luxembourg	35.9	6,318
Hungary	7.3	1,285
Malta	12.3	2,165
Netherlands	34.0	5,984
Austria	31.5	5,544
Poland	8.4	1,478
Portugal	13.1	2,306
Romania	4.6	810
Slovenia	15.6	2,746
Slovakia	9.7	1,707
Finland	32.3	5,685
Sweden	37.4	6,582
United Kingdom	22.3	3,925

Source: Eurostat database: Labour cost levels by Member State 2000-2014 (Last update: 26-03-2015 (lc_lci_lev)

Table 61 sets out whether or not it is likely that costs will be incurred for different categories of administrative actions depending on whether an existing climate mitigation action is extended in its reach (i.e. 'more of the same') or whether it is introduced as a new action within the CAP (New measures may arise as part of a measure that is already implemented or, in the case of the RDPs, through the use of a completely new measure, hitherto not used. At this stage the table does not break down the information by different CAP mechanisms (this analysis is carried out in subsequent sections), but it does provide an overview of the likely scale of costs to inform the subsequent assessment of CAP instruments.

Table 61: Likely additional administrative effort required depending on whether action is a) new or b) already in place but implementation needs to be expanded

Phase	Type of activity	Detailed activity	Likely additional effort if 'more of the same'	Likely additional effort if new action introduced
Preparation	Data gathering and assembly	• baseline and target levels for emissions – could include commissioning of research projects and / or using in-house or agency expertise	• none	• would need to be developed
		• Identifying which of the range of CAP measures (or which combination) would be most appropriate for implementing a particular climate mitigation action	• none	• Yes
	Measure design	• Assessment of cost-effectiveness of action	• Checks needed to ensure that expansion of action is still value for money (vfm)	• Yes
		• identification of rules (which may include detailed prescriptions) for the measures to achieve desired outcomes,	• Minimal	• Yes
		• Legal work and consultation as a precursor to introduction of measures	• Possibly	• Probably
		• Determination of target level or type of uptake / areas / farming systems/ soil types for measure implementation etc,	• Potentially some work depending on existing targeting – but should build on what is already in place	• Yes – scale depends on what sort of information is already available
		• identification of control criteria	• none	• Yes
Implementation	Measure delivery	• Costs of staff to devise a procedure and process applications and make payments	• Possibly – but probably will be limited, as increased applications for one type of action often are likely to mean reductions elsewhere given limits to budgets	• Yes, but often will be subsumed within existing workloads and staffing levels
		• Training costs for staff	• Minimal	• Yes
		• Development of official measure guidance	• Some to include any new details	• Yes
		• Provision of technical advice, training – on-line, face-to-face, in groups/individually	• Some but likely to be subsumed into overall FAS or other advice provision	• Yes
	Compliance control	• Costs of staff to carry out controls – paper and IT-based checks and in-field inspections;	• Possibly – but likely to be limited as will be constrained by resourcing and budgets	• Yes

Phase	Type of activity	Detailed activity	Likely additional effort if 'more of the same'	Likely additional effort if new action introduced
		• Costs of imposing penalties if required	• Yes – but part of existing processes	• Yes, but likely to be subsumed within existing processes
		• Costs of any additional technology or means of controls – remote-sensing etc.	• Possibly – although should be able to be subsumed within existing processes	• Yes, but should be able to be subsumed within existing processes
Monitoring	Monitoring and evaluation	• Research costs if specific evaluations/assessments need to be commissioned;	• None	• Yes
		• Identification of suitable indicators	• Existing indications should suffice	• Probably
		• Costs to measure the baseline and progress against relevant CAP MEF indicators	• None	• Yes

Cross-compliance

This section assesses the potential additional administrative costs/efforts required either to introduce new or to extend existing climate mitigation actions into cross-compliance.

There are relatively few climate mitigation actions that are appropriate to be covered under cross-compliance under the 2014 to 2020 CAP framework. Of the 22 climate mitigation actions considered within this study, only five are considered relevant for cross-compliance, given the nature of the GAEC standards and taking into account control and verification requirements. These are: conversion of arable to grassland (buffer strips); woodland management (including woody features, such as hedgerows); leaving crop residues on the soil surface; ceasing burning of vegetation and crop residues; and use of cover/catch crops and reducing bare fallow.

Of these, two should already be included within the GAEC standards of all Member States to the maximum extent possible and therefore no additional administrative efforts should occur (although in practice, some additional administrative effort may be required to improve implementation). These are:

- “conversion of arable to grassland”, which relates to the requirement to introduce buffer strips in accordance with the Nitrates directive (GAEC1); and
- “ceasing burning of vegetation and crop residues”, (should be covered already, usually under GAEC6) .

For the remaining three climate mitigation actions:

- “Management of woody features” could lead to the inclusion of additional types of landscape features, not currently covered, under GAEC 7;
- “Leaving crop residues on the soil surface” could be introduced as an additional requirement under GAEC 4 (minimum soil cover); and
- Member States could include (but are not required to include) the use of “cover crops and reducing bare fallow” under either GAEC 4 (minimum soil cover) or possibly GAEC 5 (limiting soil erosion). Indeed provisions for this are already in place in some Member States.

In the cases where the climate mitigation actions identified are already in place as GAEC standards and there is the possibility to extend their application more widely (although in some cases they will apply already to all relevant farmland), the overall level of administrative effort required is likely to be very low for most categories (< €10,000 / < 2 person months per climate mitigation action – and likely to be at the lower end of this band). Where data gathering is necessary, a higher level of costs may be incurred, especially if detailed survey work is required. However, the costs of any such data gathering activities would be shared across all actions for which such information is needed and across other cost categories (e.g. monitoring and evaluation) and only a portion would be attributable to this action.

The sort of administrative effort that would be needed to **extend** the reach of an existing GAEC standard would include:

- *Preparation (data gathering and assembly*): additional efforts may be required to gather evidence to assess those situations (e.g. soil types/slopes) or farms to which the GAEC standard should be extended. The costs here could be in a higher range if any detailed survey work is required.
- *Preparation (measure design*) – consideration as to whether or not any changes to the rules need to be put in place as well as targeting the climate mitigation action to additional situations which might be relevant (e.g. soil cover crops on particular soil types and/or on slopes above a certain gradient).

- *Implementation (measure delivery*): it may be that a review is required of the guidance materials if changes to the details of the GAEC standard have been introduced.

- *Implementation (control and verification*): initially none, as the systems will already be in place.

- *Monitoring and evaluation*: initially none, as the systems will already be in place.

In cases where the relevant climate mitigation actions are introduced as a new element within the GAEC framework (i.e. within existing GAEC standards), somewhat higher administrative efforts can be anticipated, but these are still likely to be very low for most categories (in most cases < €10,000 / < 2 person months per climate mitigation action). The only situation in which costs may be higher is in cases where new data are required for assessing the conditions or zones in which the standard should apply (slope gradient, soil type etc.) and for the control and verification of the payment (e.g. remote sensing data where these are not already in place).

The sort of administrative effort that would be needed to introduce a climate mitigation action as a **new element** within the GAEC framework is described in Table 1 of Annex 4 and includes:

- *Preparation (data gathering and assembly*): evidence gathering to assess where the GAEC standard should be targeted – costs will be higher if any detailed survey work is required.

- *Preparation (measure design*): to develop the rules and control criteria.

- *Implementation (measure delivery*): to develop new guidance materials and provide advice on the new measures via the Farm Advisory System.

- *Implementation (control and verification*): the level of effort/costs required will depend on the number of farms on which the measure applies and therefore the scale of checks required. Higher costs will be incurred if new remote sensing data are required.

- *Monitoring and evaluation*: To develop the methods and indicators for monitoring the new action and their incorporation into the existing CAP monitoring and evaluation requirements/framework.

Pillar 1 green direct payments

This section assesses the potential additional administrative costs/efforts required to introduce new or extend existing climate mitigation actions into Pillar 1 green direct payments.

There are relatively few climate mitigation actions that are appropriate to be covered under the Pillar 1 greening payments under the 2014-2020 framework. Of the 22 climate mitigation actions considered within this study, only 5 are considered relevant to green direct payments, given the nature of the measures available under these payments and taking into account control and verification requirements. These are:

- "Conversion of arable land to grassland to sequester carbon in the soil" (e.g. where buffer strips are made eligible to contribute to the establishment of EFA measure)
- "Agroforestry (e.g. where agroforestry or short rotation forestry" – where eligible – or certain specified SRC species, are made eligible to contribute to the EFA measure)

- “Wetland/peatland conservation” (the rules on the designation of environmentally sensitive permanent grassland (ESPG) include wetland/peatland and other grassland on carbon rich soils)
- “Woodland management” (e.g. where woodland – where eligible – or woody landscape features are identified as eligible to contribute to EFA)
- “Use of cover/catch crops and reducing bare fallow” (e.g. where cover crops or fallow land (not left bare) are identified as eligible to contribute to the EFA measure).

In the case where the climate mitigation actions identified are already in place under the existing Member State choices for implementation of green direct payments and there is the possibility to extend their use (in most cases they will apply already to all relevant farmland), the overall level of administrative effort required is likely to be very low for all categories (< €10,000 / < 2 person months per climate mitigation action – and likely to be at the lower end of this band).

In the cases where some extension of the measures is possible the sort of administrative effort that would be needed would include:

- *Preparation (data gathering and assembly):* none as evidence would already be gathered.
- *Preparation (measure design)* – none if the measure is already chosen for implementation in a Member State, its design will already have been carried out.
- *Implementation (measure delivery*): possible review required of the guidance materials if any changes to the details of the measure requirements have been introduced (e.g. changes to whether or not fertilizers are permitted on cover crops etc).
- *Implementation (control and verification)*: minimal, as the systems will already be in place although if the revised measures capture more farmers then there may need to be additional control checks.
- *Monitoring and evaluation*: none, as the systems will already be in place.

In the case where the relevant climate mitigation actions are introduced as a new element within the green direct payments[50], slightly higher administrative efforts can be anticipated, but these are still expected to be very low for most categories (in most cases < €10,000 / < 2 person months). The only situation in which costs may be higher is in cases where new data are required for the control and verification of the payment (e.g. remote sensing data where these are not already in place).

The sort of administrative effort that would be needed to introduce new climate mitigation actions within the green direct payments is described in Table 2 of Annex 4 and includes:

- *Preparation (data gathering and assembly*): evidence gathering to underpin the rationale for including the action, to assess which actions would be appropriate in which situations and the possible need to invest in remote-sensing data for control purposes if this does not currently exist.
- *Preparation (measure design):* to develop the rules and control criteria.

[50] Member States can revise their implementation of the green direct payments each year by notifying the Commission in August of the year preceding the year in which the payments come into force.

- *Implementation (measure delivery):* to develop new guidance materials and provide advice on the new measures via the Farm Advisory System. Also possible additional time could be required for processing IACS claims.

- *Implementation (control and verification):* the level of effort/costs will depend on the number of additional checks and controls required. Some more significant costs may occur if new remote sensing data are required.

- *Monitoring and evaluation:* To develop the methods and indicators for monitoring the new action and their incorporation into the existing CAP monitoring and evaluation requirements/framework.

Rural Development Programmes (under the EAFRD)

This section assess the potential additional administrative costs/efforts required to introduce new or extend existing climate mitigation actions into Rural Development Programmes (RDPs)

Our assessment suggests that all of the 22 climate mitigation actions considered within this study have the potential either to be implemented via RDPs, using a range of different measures, or their implementation can be supported via RDPs, for example through the provision of advice and training.

As with cross-compliance and the green direct payments, in situations where the climate mitigation actions identified are already in place within RDPs and there is the possibility to extend their use, the overall level of administrative effort required is likely to be fairly low (< €10,000 / < 2 person months) per climate mitigation action for most categories. Where data gathering is necessary, for example to inform targeting decisions, a higher level of costs may be incurred, although in many cases, such costs would be shared across multiple actions and across other cost categories (e.g. monitoring and evaluation).

The sort of administrative effort that would be needed to **extend the use of existing actions** includes:

- *Preparation (data gathering and assembly):* in many cases there may be no additional efforts required as the evidence gathered for the implementation of the existing climate mitigation action will suffice. In some cases, a small amount of data gathering may be required to inform decisions on how the climate mitigation action should be targeted in locations where it is not currently operating.

- *Preparation (measure design)* – here the main task required would be to identify which additional areas or beneficiaries should be the focus of the extended operation of the climate mitigation action and establishing any revisions to eligibility criteria that might be necessary. This may involve liaison with stakeholders and farming, and forestry interests in the areas affected and would be more time consuming for some measures than others, particularly where the climate mitigation action involves land use change or significant changes to farming practices. However, if the climate mitigation action is already in place with the RDP, much of this liaison and consultation should have already taken place during the RDP's development. Other design aspects of the measure will already be in place

- *Implementation (measure delivery):* a review would be required of the guidance materials if any changes to the details of the scheme requirements have been introduced by extending the use of the climate mitigation action. There may also be additional time required to process additional applications, but this will be dependent on the design of the scheme. For example, if a scheme is open to all farm and/or land managers, then applications may increase as would the time required to process them.

- *Implementation (control and verification):* The additional efforts in this category are likely to be minimal, as the systems will already be in place. If the revised measures lead to more agreements than previously, then there will need to be additional control checks.

- *Monitoring and evaluation*: there should be no additional efforts required for monitoring and evaluation, as the systems and indicators already will be in place.

In the second situation where the relevant climate mitigation actions are introduced as a new element within RDPs, somewhat higher administrative efforts can be anticipated, but these are still anticipated to be fairly low (estimated to be either in the first or second band (< €10,000 / < 2 person months or €10,001 to €25,000 / 2 to 6 person months). The only situation in which costs may be higher is in cases where new data are required to inform the targeting of the action or for its control and verification (e.g. remote sensing data where these are not already in place).

The sort of administrative effort that would be needed to **introduce a new action** within existing RDP measures and schemes is described in Table 3 of Annex 4 and includes:

- *Preparation (data gathering and assembly):* Evidence gathering is likely to be required to inform decisions about the targeting of the action, e.g. which areas, which soil types, which types of farms etc. For some of the more innovative climate mitigation actions, further research may be needed to understand better their GHG mitigation potential in different circumstances and the situations in which there is a need for public support. Information would also be needed on how best to measure the impact of the action – both to inform GHG reporting but also to conform to CAP rules. Data will also be needed to assess the cost-effectiveness of the climate mitigation action in different situations. It would be unlikely for data to be sought for just one climate mitigation action at a time. Rather information would be gathered to assess these aspects for a range of actions at the same time, achieving economies of scale regarding the staff time required.

- *Preparation (measure design)* – Time would be required to develop the rules, target areas, control criteria and payment rates. In some cases, where the climate mitigation actions are more innovative in nature and have not been used to any great extent (or at all) in RDPs to date, there will be greater time required to determine what it would be feasible to support under the EAFRD The efforts are also likely to be higher for climate mitigation actions that have a greater impact on land management/land use – e.g. peatland restoration. This is because of the time needed to engage with stakeholders, including farmers' organisations in scheme design and targeting as well as with land managers to encourage uptake of the management proposed. However, despite this, the effort is still unlikely to be above band 2 (€10,001 to €25,000 / ~2 to 6 person months) for a single action and more likely to be in band 1 (< €10,000 / ~ 2 person months). As above, these sorts of consultations are more likely to take place at the level of the scheme rather than of a single action and so it is difficult to estimate costs per climate mitigation action.

- *Implementation (measure delivery):* There would be some costs involved in developing new guidance materials and to ensure the availability of advice on the new measures via the Farm Advisory System. Both advisers and delivery staff would need to be trained so that they understood the objectives and rules of the new actions being introduced. There may be additional staff time required to process applications, although as stated above, this will depend on the design of the scheme.

- *Implementation (control and verification*): the level of additional effort/costs will depend on the number of additional checks and controls required. More significant costs may occur if new remote sensing data are required (covered under data gathering). In situations where only the advice and training measures are used, there will be few additional efforts required as the systems are already in place to control these types of measures.

- *Monitoring and evaluation*: Additional efforts will be required to develop the methods and indicators for monitoring the new action and their incorporation into the existing CAP monitoring and evaluation requirements/framework. Where only advice and training measures are used, there are unlikely to be additional costs as the systems that are already in place for monitoring and evaluating those measures are already in place.

5.6 Conclusions

The lack of published information on the administrative costs of implementing different policies in Member States is a real constraint to obtaining consistent and reliable estimates to use in these sorts of policy assessments. Given this, the analysis in this chapter is indicative at best and is based mainly on expert judgement, based on the direct experience of the study team in the design and monitoring of CAP schemes. More systematic reporting of the costs incurred by public administrations in the implementation of different policies is needed to inform such calculations in the future.

Given that the CAP administrative structures for the period to 2020 are already in place (or in the process of being put in place), as required under the 2013 regulations, the bulk of administrative efforts/costs associated with the CAP are already included within the baseline. This means that the potential additional administrative efforts / costs that may be incurred in extending the use of or introducing new climate mitigation actions into the CAP are expected to be minimal for most climate mitigation actions under most CAP instruments.

There are two main exceptions to this. Firstly, where the climate mitigation actions are more innovative and require more up front research or data gathering to assess their feasibility for implementation and how they should be targeted. Secondly, those situations in which control and verification rules require new data to be collected, such as remote-sensing data where this is not currently available.

It is important to remember that the decision to extend or introduce new climate mitigation actions within cross-compliance, greening or its RDPs remains with the Member State or region. The likely overall additional administrative efforts for the EU-28 will therefore depend on: a) the current CAP implementation choices made by Member States; and b) the extent to which they are willing to extend the use of climate mitigation actions where these are already in place or introduce new climate mitigation actions where these are not currently used. However, whatever these choices are, the budget available to national and regional governments to administer the CAP is unlikely to increase. Since most administrations already have fairly efficient CAP administration systems in place, any additional staff time or operational costs required to improve the CAP's contribution to climate mitigation will need to be carried in as cost-efficient way as possible. Efficiencies can be achieved by coordinating efforts between government departments, particularly for sharing the costs of data gathering and processing. For example, the inclusion of LULUCF within future Member State GHG emission reduction targets and the requirements for reporting and accounting emissions from cropland and grazing land management under EU Decision No 529/2013 mean that efforts are already required to improve data on emissions from land use and land management activities. Administrations can therefore use the NIR emissions data relating to the Agriculture, Forest and Other Land Use (AFOLU) sector when considering the implementation of new climate actions within different policy mechanisms within the CAP, In addition, some of the data required for GHG emission reporting can in turn be provided by the CAP control systems.

6 Articulation with the CAP and overcoming barriers to implementing climate mitigation actions

This chapter first summarises the extent to which mechanisms within the CAP, as currently formulated, have the potential to be used as a means for stimulating climate mitigation actions. It then reviews the main barriers to improving the uptake of climate mitigation actions by managing authorities and farmers. It follows on from chapter 3 in which we discussed in more detail specific farm-level barriers to uptake of the individual climate mitigation actions, and the additional administrative costs and effort required of administrations to increase uptake within the CAP. Here we provide a qualitative overview of the different types of obstacle or barrier which are inhibiting appropriate action, distinguishing between those applying to governments, and farmers/land managers where relevant, and suggesting ways to overcome them.

6.1 The articulation of policy mechanisms within the CAP with climate mitigation actions

The agriculture sector remains a significant emitter of non CO_2 greenhouse gas emissions and in some countries these constitute a considerable proportion of total greenhouse gas emissions[51]. Considering only CO_2 emissions from the LULUCF sector, overall the sector is a net sink which has remained fairly stable since 1990. However this sink is expected to shrink over the coming years linked to a rise in anticipated emissions from forest management due to aging forest stands and increased harvesting, predominantly for energy use (Böttcher and Graichen, 2015).

Given the EU's emission reduction goals, there is therefore a valuable opportunity to extend the use of those climate mitigation actions that have been shown to have significant mitigation potential in different farming systems in particular regions of the EU. This can be done by encouraging greater uptake by farmers of those that are already technically feasible and cost-effective as well as encouraging the implementation of actions that are less commonly used currently in the short, medium and longer term.

To achieve this requires action on a number of different levels. As a first step it is important to create the enabling conditions at a strategic level to provide a clear set of priorities and goals for the agricultural sector in relation to reducing greenhouse gas emissions, including the CO_2 emissions relating to land use and land use change (LULUCF). Currently there are no clear emission reduction targets specifically for the agricultural sector, either for non-CO_2 or CO_2 emissions. Whilst there are reasons for this, in practice it leaves the agricultural sector and some of the responsible Member State authorities without a clear strategy or goals to attain in this area. Indeed, two experts interviewed for this project referred to a lack of clarity in EU and CAP policies, one commenting that the 'EU arguments are unclear, with many different objectives, and since the start of the last reporting period and the Lisbon objectives it is not clear whether the priority for agriculture is mitigation or adaptation'. The other suggested that the objective of sustainable land management was unclear, particularly where objectives of reducing GHG emissions and keeping sufficient land in place for food production come into conflict.

Member States could develop more detailed and specific sector related strategies (where these are not in place already) to motivate greater understanding and investment in the farm and forest sectors. Considerable effort then needs to be put into raising the awareness of these

[51] Member States with non-CO2 emissions above the EU average (10.2%) are (in ascending order) Spain, Portugal, Croatia, Sweden, Hungary, Romania, Hungary, Denmark, France, Latvia, Lithuania and Ireland.

climate priorities and goals to stakeholders and individuals in the land use sector, systematically incorporating these into policies to provide the sector with clearer expectations regarding the direction of travel required to help inform decision making. Ensuring that the appropriate policy tools are in place to enable action is then necessary and improving monitoring and reporting against these priorities is also required as a means of establishing and demonstrating progress.

The climate mitigation actions identified in this study as having the greatest mitigation potential in Member States (see Chapter 4) can be divided into four categories.

1. Actions that are likely to have **zero net cost to the land manager, or offer cost savings** to the farm or other business and therefore make good economic sense in their own right (e.g. improved nitrogen efficiency). In principle, these are likely to require only awareness raising and training initiatives by public authorities to achieve more widespread uptake. Such initiatives can be organised and funded in different ways, including under the CAP or via other nationally, regionally or locally funded advisory services. Where funded under the CAP, advice and information could be provided through setting up demonstration activities and information actions; and/or setting up farm and forestry advisory services. These could provide information on:
    a. The GHG emissions of the relevant farming practices;
    b. the contribution of the agricultural sector to mitigation through improved farming and agroforestry practices; and
    c. how to improve and optimise soil carbon levels through the Member State's Farm Advisory Service[52].
2. Actions that are likely to **impose a net cost on farmers and where there are suitable policy measures within the CAP** to provide direct incentives to encourage the uptake of actions, and to carry out pilot projects, as well as to fund the provision of advice and training. Woodland planting, conversion of land from arable to grassland or introducing catch and cover crops on arable land are examples. Incentives are available to some extent under the greening measures in Pillar 1, but are more often provided through measures involving entry into voluntary agreements[53] or the receipt of investment or facilitation support[54] via national or regional Rural Development Programmes, funded via the European Agricultural Fund for Rural Development (EAFRD).
3. Mitigation actions with significant mitigation potential, where there are likely to be net **costs to the farmer, but where the options for support under the CAP, particularly direct financial support, are limited to supporting measures to provide advice and training.** This may be because of the design of the measures or because of the difficulty or cost of verifying actions at farm level. Examples of these types of actions relate mainly to the livestock sector (e.g. livestock disease management (significant in most countries), the use of sexed semen for breeding dairy replacements and the use of feed additives (likely to be particularly relevant in countries such as Ireland and the Netherlands).
4. Mitigation actions where changes in practice are required with **some net cost to the farm business, but where the CAP is not necessarily a suitable route for incentivising increased uptake**. This is the case, for example with the use of nitrification inhibitors. Even if outstanding issues relating to environmental or food safety arising from their use are resolved so public policy objectives are satisfied, it is unclear what sort of incentive could be made available via the CAP that would encourage the substantial scale of uptake required to have a significant climate mitigation impact. One approach could be to make the use of nitrification inhibitors a requirement of entering an agri-environment-climate agreement on arable land

[52] Provision of this information is an option for Member States, not a required part of the Farm Advisory Service. Article 12.3 and Annex 1 of Regulation (EU) 1306/2013
[53] For example via the agri-environment-climate measure, the forest-environment measure, the organic farming measure, measures in Natura 2000 and WFD priority areas (for agriculture and forestry) and other forestry measures promoting afforestation and agro-forestry.
[54] For example investments in physical infrastructure and the provision of advice and training

perhaps, although verification could present problems and the scale of uptake might be limited. Perhaps an alternative and more certain means of ensuring their widespread use might be a requirement under other legislation to require their incorporation into the manufacture of all N fertilizers used in the EU after a certain date.

Support under the CAP

Measures within the CAP therefore have an important role to play in encouraging and supporting the agricultural and forest sectors to reduce greenhouse gas emissions and increase removals. More strategic emphasis to enhance the climate dimension of the CAP would therefore be valuable as a means to achieving climate priorities in the agricultural sector.

The current CAP legislative framework running from 2014 to 2020 contains many measures which have the potential to be implemented by Member States in a way that could contribute to climate mitigation activities in relation to agriculture and forestry (see chapter 3 and Annex 5).

Key amongst the CAP measures are:

- **A selection of cross-compliance GAEC standards**: GAEC 1 (buffer strips adjacent to water courses), GAEC 4 (minimum soil cover), GAEC 5 (land management to limit erosion), GAEC 6 (protection of soil organic matter) and GAEC 7 (retention of landscape features).
- **Greening measures in Pillar 1:** the maintenance of permanent grassland measure, particularly the designation of land as environmentally sensitive permanent grassland on which ploughing is banned, both within Natura 2000 areas (mandatory) and outside Natura 2000 areas (voluntary); the EFA measure, particularly the following elements: fallow land, landscape features, buffer strips, afforestation, agro-forestry, strips along forest edges, SRC, catch crops and green cover, N-fixing crops. The climate mitigation benefits of many of these options available to Member States will depend on the specific rules adopted on how the element concerned is managed (e.g. whether use of fertilizers is permitted or not).
- **Rural Development measures**, including:
    - agri-environment-climate payments,
    - organic conversion and maintenance payments,
    - investments in physical assets – including non-productive payments to support the agri-environment-climate measure,
    - forest environmental and climate payments,
    - payments for the establishment and maintenance of agro-forestry
    - afforestation and creation of woodland
    - prevention and restoration of damage from forest fires, natural disasters
    - investments to improve the resilience and environmental value of forest ecosystems

These RDP measures, which are aimed directly at farm or forest management or land use, can be reinforced by coordination with indirect support from so called ‘soft’ measures such as knowledge transfer, advisory services, cooperation and networks. Rural development measures help provide funding for these activities, for example:

- the cooperation measure can, amongst other things, provide support for pilots and development of new agricultural products, practices, processes and technologies; joint action for mitigating or adapting to climate change, to encourage landscape scale implementation; and provide support for drawing up forest management plans

- training, demonstration activities and information provision
- EIP operational groups and pilot projects

Focussing on the second group of climate mitigation actions highlighted above (i.e. those where there is a net cost to the business and where the CAP provides suitable policy tools to support directly their uptake), the analysis carried out in this study shows that many of those with the greatest mitigation potential in most Member States, particularly those related to the management of agricultural land, crops and soils can be supported under the measures available within the CAP without impediment.

The extent to which CAP requirements, incentives or support for uptake of these actions are either currently available to farmers in Member States (where there is considerable discretion regarding the content of CAP measures) or then subsequently taken up by farmers, however, has not been possible to identify as the data on the utilisation of most Pillar 2 rural development measures were not available at the level of detail required for this type of assessment. This is due to the fact that only a few of the mitigation actions reviewed for this study are directly equivalent to a specific CAP measure, for example RDP measures for afforestation and new agroforestry, or the cross-compliance GAEC 6 standard prohibiting arable stubble burning. Others generally form part of a range of specific options that are available for funding under a particular measure, but the necessary level of detail about their application is not generally available in the data in the public domain, particularly for Pillar 2 measures.

Examples of actions that could in principle be supported under several CAP measures are set out in Table 62.

Table 62: Potential CAP measures available to support actions identified as having high mitigation potential

	Cross-compliance	Pillar 1 Greening measures	Pillar 2
Cover/catch crops	No directly relevant standards In some cases the use of cover crops under greening in areas vulnerable to soil erosion is a requirement of the soil GAEC standards (e.g. GAEC 5 - minimum land management to limit soil erosion; and GAEC 6 maintenance of soil organic matter)	Can be supported under the - Ecological Focus Area measure (offered to farmers in 19 MSs in 2015) - the crop diversification measure	Can be supported under the: - agri-environment-climate measure or - organic farming measure
Biological N fixation in rotations and grass mixes	No relevant standards	There is potential on some arable land under the - Ecological Focus Area measure (through the use of N fixing crops - offered to farmers in all MSs in 2015) and - the crop diversification measure under Pillar 1 Although neither measure requires these crops to be put into rotations or with grass mixes.	Can be supported under the agri-environment-climate measure
The conversion of arable land to permanent grassland to sequester carbon in the soils	Encouraged to some extent through GAEC 1 to introduce buffer strips alongside water courses	Supported under the EFA measure (through the use of buffer strips, an option available to farmers in 17 MSs in 2015)	Can be incentivised under the - agri-environment-climate measure, - associated non-productive investments and - possibly under the measure providing compensation to farmers subject to River Basin Management Plans if conversion of arable to grassland is a requirement under the Programme of Measures.

	Cross-compliance	Pillar 1 Greening measures	Pillar 2
Prevention of deforestation and removal of farmland trees	Prevention of the removal of farmland trees can be supported by the requirement under - GAEC 7 to retain landscape features in countries which choose to include copses, lines and groups of trees and individual trees within this standard. - SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs	Supported indirectly by the EFA measure which permits certain afforested areas (available in 14 MSs) as well as woody features to meet the EFA obligation.	Possible to be supported indirectly through support for the management of farm woodland and individual farmland trees – e.g. via: - forest-environment-climate measure - agri-environment-climate measure
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	Not applicable - the GAEC standards generally require retention of these types of habitats not their ongoing management	It is possible to support hedgerows and trees on agricultural land as part of the EFA measure under which Member States can include a range of landscape features to count towards the EFA obligation, e.g. - hedgerows (offered in 13 MSs in 2015); - isolated trees (offered in 13 MSs in 2015); - trees in line (offered in 16 MSs in 2015); - trees in groups (offered in 17 MSs in 2015);	A number of measures are relevant under Pillar 2 including: - support for non-productive investments linked to the achievement of agri-environment-climate objectives (M4.4) for restoration of farmland trees and hedges; - agri-environment-climate payments, as equivalence for EFAs or separately (M10.1) for management of farmland trees and hedges; - support for prevention of damage to forests from forest fires and natural disasters and catastrophic events (M8.3) - support for restoration of damage to forests from forest fires and natural disasters and catastrophic events (M8.4) - support for investments improving the resilience and environmental value of forest ecosystems (M8.5) - compensation payment for Natura 2000 forest areas (M12.2)

	Cross-compliance	Pillar 1 Greening measures	Pillar 2
			- payment for forest-environmental and climate commitments (M15.1) - support for the conservation and promotion of forest genetic resources (M15.2) - support for joint action undertaken with a view to mitigating or adapting to climate change and for joint approaches to environmental projects and ongoing environmental practices (M16.5) - support for drawing up of forest management plans or equivalent instruments (M16.8)
Woodland planting	Not relevant	Can be supported indirectly under EFAs, where areas of woodland created with RDP or equivalent national support, or new hedges, trees in lines or groups and isolated trees on or adjacent to arable land can count towards the EFA obligation. 14 Member States have permitted afforested areas as eligible for the EFA measure	Support can be provided through - the non-productive investments measure linked to the achievement of agri-environment-climate objectives (M4.4) for planting individual trees, groups of trees and hedges as well as through payments for afforestation and - creation of woodland on both agricultural and non-agricultural land (M8.1)
Improved on-farm energy efficiency	not relevant	no relevant measures	Relevant CAP measures could include: - vocational training and skills acquisition (M1.1) for example in techniques to improve fuel efficiency such as eco-driving and tractor maintenance - demonstration activities and information (M 1.2), for example on developing a fuel use action plan - setting up farm and forestry advisory services (M 2.2) to provide through the Member State's Farm Advisory Service - support for investments in infrastructure related to the development, modernisation or adaptation of agriculture and forestry (M4.3)

	Cross-compliance	Pillar 1 Greening measures	Pillar 2
Soil and nutrient management plans	in some countries soil management plans are required as a means of identifying the actions required to comply with soil GAEC standards (e.g. GAEC 5 - minimum land management to limit soil erosion; and possibly GAEC 6 maintenance of soil organic matter)	no relevant measures	The development of soil and nutrient management plans as a pre-cursor to actions on the ground can be supported via: - demonstration activities and information actions (M 1.2); - setting up farm and forestry advisory services (M 2.2) and - the agri-environment-climate measure (M10.1)
Zero tillage, which has significant mitigation potential in a small number of the more arid Member States (Cyprus, Greece, Spain and Portugal):	Member States can specify zero tillage must be carried out in certain areas sensitive to soil erosion under GAEC 5 (minimum land management to limit soil erosion)	no relevant measures	Can be supported under measures such as: - support for investments in agricultural holdings (M4.1) and - agri-environment-climate payments (M10.1) targeted at land where there is a significant risk of soil erosion (provided the requirements of verification and payment control can be met) - advice and knowledge transfer activities using demonstration activities and information (M 1.2), for example to improve farmers' understanding of how to address potential problems, (e.g. via the use of mechanical weed control, integrated pest management or - setting up farm and forestry advisory services (M2.2). - Pilot projects could also be instigated used the cooperation measure (M16).

Other climate mitigation actions which may have mitigation potential but at a smaller scale can also be supported via the CAP, particularly Pillar 2. This could include the conversion of arable land to grassland to protect carbon rich soils or enhance soil carbon and wetland and peatland conservation and restoration (via the agri-environment-climate measure). In the case of protecting peatland, or more generally the protection of carbon rich soils, where these are on grassland they can be protected from ploughing through the designation of Environmentally Sensitive Permanent Grassland (ESPG) in Natura 2000 areas (ESPG in these areas must be protected where this is deemed necessary). They can also be protected from ploughing outside Natura 2000 areas, although this is voluntary for Member States and land has only been designated in four Member States. From information available to date, it does not look as if the areas designated outside Natura 2000 areas comprise carbon rich soils. Carbon rich soils can also be maintained and restored via Pillar 2 support, mainly using the agri-environment-climate measure in conjunction with the non-productive investment measure.

In summary, a wide suite of measures can be deployed to pursue impacts over varying timescales, often in specific localities. Both arable and livestock systems are eligible but there is probably more potential in the former. However, it must be noted that the reach of these measures in terms of area and numbers of farms affected could be limited in many cases at least without a substantial change in Member State priorities (see section below for more details).

Table 63: Relevance of CAP measures to supporting implementation of climate mitigation actions

	Cross-compliance							Pillar 1 Greening		
	GAEC1	GAEC2	GAEC3	GAEC4	GAEC5	GAEC6	GAEC7	CD	EFA	PP
Mitigation Action	Buffer strips	Irrigation	Groundwater	Min Soil cover	Min land mgt to limit soil erosion	Maintenance of SOM	Landscape features		afforested agricultural land, new agroforestry, existing and new 'woody' landscape features, buffer strips and N-fixing crops can qualify as EFA	environmentally sensitive permanent grassland must be protected in Natura 2000 areas and may also be protected outside these areas
Land Use										
Conversion of arable land to grassland to sequester carbon in the soil	■				■				■	
New agroforestry									■	
Wetland/peatland conservation/ restoration										■
Woodland planting									■	
Preventing deforestation and removal of farmland trees							■		■	
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land										
Crop Production Systems										
Reduced tillage										
Zero tillage										
Leaving crop residues on the soil surface						■				
Ceasing to burn crop residues and vegetation						■				
Use cover/catch crops									■	
Livestock Production Systems										
Livestock disease management										
Use of sexed semen for breeding dairy replacements										
Breeding lower methane emissions in ruminants										
Feed additives for ruminant diets										
Optimised feeding strategies for livestock										
Manure, Fertilizer & Soil management										
Soil and nutrient management plans					■	■				
Use of nitrification inhibitors										
Improved nitrogen efficiency										
Biological N fixation in rotations and in grass mixes								■	■	
Energy										
Carbon auditing tools										
Improved on-farm energy efficiency										

Note: EAFRD M3, M5, M6, M7, M9, M13, M17 and M19 have not been identified as being helpful for funding the climate mitigation actions identified for this study.

Key

■ (dark blue) CAP measures directly relevant to implementation of the action

(light blue) CAP measures providing indirect support for implementation of the action

Continuation of Table 63: Relevance of CAP measures to supporting implementation of climate mitigation actions

EAFRD													
			Investments in physical assets			Investments in forest area development and improving viability of forests						Agri-Environment-Climate	
	M1	M2	M4.1	M4.3	M4.4	M8.1	M8.2	M8.3	M8.4	M8.5	M9	M10.1	M10.2
Mitigation Action	Knowledge transfer & info	Advisory services	investments in agricultural holdings	investments in infrastructure for development, modernisation or adaptation of agriculture &	non-productive investments linked to AEC objectives	Afforestation / woodland creation	Establishment and maintenance of agro-forestry	prevention of damage from forest fires, natural disasters etc	restoration of damage from forest fires, natural disasters etc	investments improving resilience & environmental value of forest ecosystems	setting up producer groups	AEC payments	support for genetic resources
Land Use													
Conversion of arable land to grassland to sequester carbon in the soil	□	□			■							■	
New agroforestry	□	□					■						
Wetland/peatland conservation/ restoration	□	□			■			■		■		■	
Woodland planting	□	□			■	■							
Preventing deforestation and removal of farmland trees	□	□											
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	□	□			■			■	■	■		■	
Crop Production Systems	□	□											
Reduced tillage	□	□										■	
Zero tillage	□	□	■									■	
Leaving crop residues on the soil surface	□	□											
Ceasing to burn crop residues and vegetation	□	□											
Use cover/catch crops	□	□										■	
Livestock Production Systems													
Livestock disease management	□	□											
Use of sexed semen for breeding dairy replacements	□												
Breeding lower methane emissions in ruminants													
Feed additives for ruminant diets	□												
Optimised feeding strategies for livestock	□	□											
Manure, Fertilizer & Soil management													
Soil and nutrient management plans	□	□										■	
Use of nitrification inhibitors													
Improved nitrogen efficiency	□	□											
Biological N fixation in rotations and in grass mixes	□	□										■	
Energy													
Carbon auditing tools	□	□											
Improved on-farm energy efficiency	□	□		■									

Note: EAFRD M3, M5, M6, M7, M9, M13, M17 and M19 have not been identified as being helpful for funding the climate mitigation actions identified for this study.

Key

■ CAP measures directly relevant to implementation of the action

□ CAP measures providing indirect support for implementation of the action

Continuation of Table 63: Relevance of CAP measures to supporting implementation of climate mitigation actions

EAFRD												
	Organic Farming		N2K & WFD payments				Forest Environment-climate		Cooperation			
	M11.1	M11.2	M12.1	M12.2	M12.3	M14	M15.1	M15.2	M16.2	M16.5	M16.8	M20
Mitigation Action	Organic Conversion	Organic maintenance	N2K agriculture	N2K forest areas	Agricultural areas within RBMPs	Animal Welfare	Forest environmental and climate commitments	Conservation and promotion of forest genetic resources	Support for pilots and development of new products, practices, processes and technologies	Joint action undertaken with a view to mitigating or adapting to climate change	Support for drawing up forest management plans	NRN network
Land Use												
Conversion of arable land to grassland to sequester carbon in the soil												
New agroforestry												
Wetland/peatland conservation/ restoration												
Woodland planting												
Preventing deforestation and removal of farmland trees												
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land												
Crop Production Systems												
Reduced tillage												
Zero tillage												
Leaving crop residues on the soil surface												
Ceasing to burn crop residues and vegetation												
Use cover/catch crops												
Livestock Production Systems												
Livestock disease management												
Use of sexed semen for breeding dairy replacements												
Breeding lower methane emissions in ruminants												
Feed additives for ruminant diets												
Optimised feeding strategies for livestock												
Manure, Fertilizer & Soil management												
Soil and nutrient management plans												
Use of nitrification inhibitors												
Improved nitrogen efficiency												
Biological N fixation in rotations and in grass mixes												
Energy												
Carbon auditing tools												
Improved on-farm energy efficiency												

Note: EAFRD M3, M5, M6, M7, M9, M13, M17 and M19 have not been identified as being helpful for funding the climate mitigation actions identified for this study.

Key

CAP measures directly relevant to implementation of the action

CAP measures providing indirect support for implementation of the action

6.2 Encouraging greater use of CAP measures for climate mitigation – political, policy and technical obstacles at Member State/regional level

As has been shown above, the CAP provides a wide range of measures that can be used to support the uptake of climate mitigation actions, however these are not always deployed in a way that promotes the widespread uptake of climate mitigation actions in the areas where these are highest priority. This and subsequent sections investigate some of the reasons for this, including the obstacles that have been identified as hindering greater use of these measures.

Member State and regional managing authorities must decide how to prioritise the use of their CAP funding and own resources to meet many different demands and policy priorities, of which climate mitigation is only one. In identifying barriers it is important to take into account the degree to which the Member States and regional governments and individual farmers who are beneficiaries of the CAP have freedom of choice in whether or not to implement specific climate mitigation actions under the CAP.

Many of the CAP measures identified as being potentially useful for encouraging the adoption of mitigation actions are, in effect, mechanisms for providing financial support to land managers for meeting certain conditions, which may or may not involve altering their present practices. Many of them are optional for Member States who may or may not choose to offer these to farmers. Where they do, the measures are usually voluntary for farmers and may or may not be attractive to them in financial or other terms. Few measures are therefore binding on all farmers. Aid schemes often can be adjusted to make them more attractive however. In consequence the pattern of use of most of the CAP measures varies considerably between Member States, the requirements of the aid schemes vary too and so does the extent and pattern of participation of farmers with differences between countries, regions, farm types, time periods etc. It is a complex and dynamic matrix of policy schemes within which the Member States have considerable discretion in the extent to which measures are focussed on and effectively turned to climate mitigation objectives. Furthermore, most of the CAP measures concerned have multiple objectives and are not dedicated specifically to climate related goals. There are consequently valid reasons for Member States to use these measures primarily for other purposes, although this then leaves them with the necessity to use other policy instruments to meet climate objectives.

In the sections that follow, we therefore look at two different but related aspects of barriers to uptake of climate actions and where feasible provide suggestions for overcoming these. First is the set of more policy or politically related reasons why Member States may not be using the CAP measures available on a significant scale to achieve climate objectives, for example: competing priorities or political inertia; synergies and conflicts with other environmental or agricultural objectives; risk averse behaviour in CAP implementation; the real and perceived complexity of CAP implementation for 2014 to 2020; under-representation of climate mitigation actions in formal CAP monitoring and reporting processes; and whether or not mitigation actions are visible in GHG emissions reporting. Secondly are the more technical barriers to deployment, such as gaps in knowledge, methodologies and data required for implementing and reporting climate mitigation actions.

It is clear from experience to date that Member States have major differences in approach and have made distinctively difference choices of policy measures. Some of these choices will of course be driven by geographical differences in land use, management, soils and climate, making some actions more suitable or effective in one place than another. Other differences will arise simply because Member States have focused their climate mitigation policies on other sectors or have chosen to encourage the uptake of mitigation actions in agriculture and forestry without using the CAP.

Subsidiarity and freedom of choice for Member States within the CAP

There are some CAP measures which all Member State or regions *must implement* (e.g. cross-compliance Statutory Management Requirements, protection of the ratio of the area of permanent grassland within the total agricultural area, identification of environmentally sensitive permanent grasslands (ESPG) in Natura 2000 areas, making available agri-environment-climate measures throughout their territory). Other CAP measures *must be implemented, but within a framework or list provided in the legislation* leaving Member States free to define the farm-level requirements in a way that is appropriate to their territory and farming systems, (e.g. GAEC standards, most greening requirements, voluntary coupled support, the farm advisory system (FAS), LEADER). For most other measures Member States can both *choose whether or not to implement* them (e.g. all other RDP measures, optional additional FAS+ advice, European Innovation Partnerships (EIP)) and also *choose what priority they give to specific climate mitigation actions* within each measure, in terms of farm level requirements, targeting and expenditure allocated.

Farmers also have choices. Those receiving CAP direct payments must implement cross-compliance requirements and, for most of the commercially significant holdings, at least some greening requirements. However, beyond that they can choose, for example which of the available greening requirements to commit to and whether or not to take advantage of advisory support, agri-environment-climate schemes, investment aid and other RDP measures. Their choices will of course be limited to those options already selected, defined and made available by the Member State or region.

The obligations and options within the CAP measures most relevant to climate mitigation are explained in more detail in Annex 5 but Table 64 gives some examples at Member State and farmer level.

Table 64: Examples of the choices available to managing authorities and farmers in relation to CAP measures

CAP measure	Extent of obligation	Choices available to Member States or regions	Choices available to individual farmers
Maintain ratio of permanent grassland within 5% of reference level	detailed requirements in CAP legislation	maintain ratio at national level	Maintain, afforest[55] or (if the national ratio has not yet dropped below the 95% limit) plough up all their permanent grassland
		maintain ratio at regional level	Maintain, afforest or (if the regional ratio has not yet dropped below the 95% limit) plough up all their permanent grassland
		maintain ratio at farm level	Maintain, afforest or plough up to 5% of their permanent grassland

[55] Farmers can afforest their permanent grassland (in an environmentally compatible way, not using fast growing species for energy production) and will not be required to reconvert the land to permanent pasture even when the ratio drops below the 95% (EU Regulation 1307/2013, Article 45(4)

CAP measure	Extent of obligation	Choices available to Member States or regions	Choices available to individual farmers
GAEC cross-compliance	define using framework in CAP legislation	freedom to define each standard's farm level obligation	observe farm-level requirements as defined by Member State/region
Greening payments	define using framework in CAP legislation	wide range of choice in options and management requirements	if eligible for greening, choose the 'best fit' options for the farm from MS/regional list
Farm Advisory System	define using framework in CAP legislation	minimum required scope, but optional to extend this	use of service is optional
Agri-environment-climate measure (Pillar 2)	required to implement the measure across all territories	define according to needs, must consider how to address environmental and climate objectives, but no obligation to spend on Priority 5, focus areas d) and e)[56]	optional
all other RDP measures (except LEADER)	optional	Where used, must consider how to address environmental and climate objectives	optional
minimum EAFRD spend on any or all of seven environment/climate measures (and, separately, minimum spend on LEADER)	requirement	must consider how to address environmental and climate objectives, but no obligation to spend on Priority 5, focus areas d) and e)	not applicable

The more choice there is available to the responsible parties at each stage in the design and implementation of the agreed CAP measures (from the Regulations through to individual land managers) the more likely it is that there will be gaps in uptake of climate mitigation actions because of legitimate alternative choices. It is also more difficult to identify the precise extent of this implementation, farm uptake of specific actions on the ground and the ensuing climate impact achieved or the reasons for making other choices. The decision-making processes at CAP, Member State and farm level are dynamic, some changing over time and of necessity, taking into account a wide range of practical and political considerations.

[56] Of the EU priorities for rural development set out in the 2013 CAP legislation Priority 5 is 'promoting resource efficiency and supporting the shift towards a low carbon and climate resilient economy in agricultural, food and forestry sectors'. Within that Priority there are five focus areas including: d) reducing greenhouse gas and ammonia emissions from agriculture; and e) fostering carbon conservation and sequestration in agriculture and forestry.

Competing priorities and policy inertia

Despite the much strengthened emphasis on climate action in both EU policy as a whole and in the CAP, Member States may choose to prioritise wider climate goals[57] or different economic, environmental or territorial objectives in focussing their CAP funded measures. This can occur for a variety of reasons, for example some of the non-climate goals, such as reduced water pollution, may be perceived as more tangible and realisable immediately - an important factor both politically and administratively when there is considerable urgency to spend RDP budgets within the relevant timeframe and monitor the results.

The 2013 CAP legislation introduced a variety of changes and significantly more discretion for Member States, thereby increasing the complexity of the policy, as Commissioner Hogan has noted. Not all the Commissions climate related proposals were adopted following the negotiation process with the Council and European Parliament. The rejection of the proposed GAEC standard for the protection of wetland and carbon rich soils during the tri-lateral negotiations on the 2013 CAP reform is one example of this[58].

Even where climate action is seen as a priority there may be political pressure within certain Member States to focus on climate adaptation actions, because many farmers have already experienced the effects of climate change (for example, more severe or frequent floods and droughts). Farmers who take a long term approach should in principle consider what land use and management changes are needed to adapt their businesses and deployment of resources to a changing climate. In contrast there is less individual economic incentive (other than wider social responsibility) for farmers or foresters to reduce GHG emissions. Such considerations can influence the choices made by public authorities and farmers, some of whom hope for future payments for carbon sequestering actions (pers. comm. Germany).

The political will to secure GHG reductions from agriculture will vary from one Member State to another for many reasons, including the overall priority given to climate policy, the relative importance of agricultural emissions within a Member State's total emissions and the extent of influence of the farming organisations.

There are different issues and choices in the forest sector, where the actions required for climate adaptation are more closely aligned with those for mitigation and it is not always easy to separate the two or reward mitigation actions. Property rights and 'ownership' of the benefits of forest management are more complex, too. For example, in Italy the carbon credits for the forest sector are 'owned' by the Ministry of Environment, not the forest managers (pers. comm.).

Synergies and conflicts with other environmental or agricultural objectives

Managing authorities are likely to seek the most cost-effective solutions to delivering the different EU priorities and focus areas they have chosen for their RDP. This could involve prioritising climate mitigation actions that also help to deliver other objectives (e.g. competitiveness, climate adaptation, reduced risk of soil erosion, floods, and diffuse agricultural pollution, biodiversity). It is helpful that many of the climate mitigation actions with the greatest mitigation potential in many Member States do have benefits for other RDP objectives. These are summarised in Table 65 below, and discussed in detail for each of the 22 climate mitigation actions in chapter 3 (Analysis of mitigation actions)

[57] For example, decarbonizing the energy sector and promote bio-energy

[58] The proposed GAEC standard 7 was for the protection of wetland and carbon rich soils including a ban on first ploughing. Annex II of proposal for a Regulation of the European Parliament and of the Council on the financing, management and monitoring of the common agricultural policy, COM(2011) 628/3, 2011/0288 (COD)

Table 65: Synergies and conflicts between selected climate mitigation actions and other environmental or agricultural objectives

Climate mitigation action and number of Member States in which this action is estimated to have significant mitigation potential (1)		**Synergy or conflict**											
		reduced soil erosion	**improved soil moisture retention and/or reduced flood risk**	**reduced diffuse pollution of watercourses**	**reduced fire risk**	**improved air quality (reduced dust or smoke or ammonia)**	**biodiversity**	**more efficient production**	**climate adaptation or resilience of farming or forestry**	**increased PPP or fertilizer inputs**	**increase in other GHG emissions**	**increased water requirement**	**agricultural production displacement**
Conversion of arable land to grassland to sequester carbon in the soil	25 MS	✔		✔ possibly ✖			✔ possibly ✖				✖ possibly		✖
New agroforestry		✔	✔	✔			✔ possibly ✖		✔	✖			✖
Wetland/peatland conservation/ restoration		✔	✔	✔	✔		✔ rarely ✖						
Woodland planting	10 MS	✔	✔	✔			✔ possibly ✖		✔				✖
Preventing deforestation and removal of farmland trees	22 MS	✔	✔	✔			✔		✔				
Management of existing woodland,	14 MS	✔	✔	✔	✔		✔ possibly		✔				

hedgerows, woody buffer strips and trees on agricultural land							✖						
Reduced tillage		✔								✖			✖ possibly
Zero tillage	4 MS	✔	✔ possibly			✔	✖ possibly			✖			✖ possibly
Leaving crop residues on the soil surface		✔	✔ possibly				✔			✖			
Ceasing to burn crop residues and vegetation					✔	✔		✔		✖			
Use cover/catch crops	all MS	✔	✔ possibly ✖	✔ possibly ✖			✖ possibly					✖ possibly	✖ possibly
Livestock disease management	17 MS							✔					
Use of sexed semen for breeding dairy replacements	2 MS IE, NL							✔					
Breeding lower methane emissions in ruminants (2)													
Feed additives for ruminant diets	3 MS BE, IE, NL							✔					✖ possibly
Optimised feeding strategies for livestock				✔		✔		✔					
Soil and nutrient management plans	all MS	✔		✔			✔	✔					
Use of nitrification inhibitors	all MS			✔									
Improved nitrogen efficiency	all MS			✔				✔					
Biological N fixation in rotations and in grass mixes	all MS			✔			✔						✖ possibly
Carbon auditing tools	all MS			✔ possibly				✔					

Improved on-farm energy efficiency	15 MS							✔					

KEY:

	Land use
	Crop production systems
	Livestock production systems
	Manure, fertilizer and soil management
	Energy
	no identified synergies or conflicts
✔	synergy
✖	conflict

It is worth noting that in many examples of the use of LIFE or EAFRD support for specific climate mitigation actions in various Member States up to 2013, the main objective was not climate mitigation but another environmental priority[59]. This illustrates the importance of multi-objective actions and policy measures which, are often selected and designed with the delivery of multiple objectives in mind. However, taking this approach can also involve trade-offs, which may blunt their efficacy for targeting purely climate objectives.

Conversely, there is likely to be a reluctance by both Member States and farmers to support climate mitigation actions where there is a risk of production displacement, or if implementation by farmers will conflict with other environmental objectives. If arable land is afforested for example there is a risk of displacement of that crop production and possibly indirect land use change (ILUC) which may happen on land outside the EU. Where the mitigation benefit is achieved through more intensive land management this may exacerbate risks to water and biodiversity for example, by requiring increased N fertilization, irrigation, or conversion of important semi-natural habitats to intensive grassland or forest.

Visibility of GHG emission reductions of climate actions in UNFCC climate reporting

A key barrier identified in the study is that Member States are less likely to be interested in using CAP funding for mitigation actions if the effect of those actions on GHG emissions will not be identified within their GHG emissions inventory and reported in their NIR.

For example, use of nitrification inhibitors (NI) has significant mitigation potential (see Figure 72): we estimated that the use of nitrification inhibitors could have the greatest mitigation potential of all actions reviewed in this study, based on an assumed high level of uptake (70%). However, at present a Tier 3 methodology would be required for the assessment of emissions in the relevant categories, and no MSs currently use a Tier 3 method. In the 2014 NIR submissions, 23 of 28 MSs used a Tier 1 method (see Table 42); Tier 1 and 2 methods use emission factors related to the quantity of N applied, so do not account for variation in time of application, type of fertilizer of other material containing N, or other efficiency measures that do not change the quantity of N applied. Emissions factors for nitrogen fertilizer using NIs at a national level would be required and detailed activity data to determine when and where applications were being made. There is scope for accounting at a lower tier if standard emission factors could be developed and agreed for fertilizer using nitrification inhibitors but this would need detailed activity data if this was used in combination with non NI fertilizers.

Examples of other MAs that have significant potential but with mitigation effects that are not reported in NIRs are carbon auditing, and biological N fixation in rotations and in grass mixes.

The experts interviewed for this project identified some of the detailed issues in aligning NIR and CAP reporting:

- It is difficult to harmonise GHG reporting rules for specific farm-level actions with CAP reporting at measure level, and the CMEF indicators are not structured in the NIR in a way that makes it possible to separate out the effects of specific actions, especially in RDP measures;
- Sampling/surveying can be a cost-effective way of monitoring land use and management for NIRs, but it is difficult to attribute the recorded results to specific CAP measures;
- In at least one federal state, the regions do not all use the same methodologies for climate reporting or have similar levels of expertise.

[59] For example, peatland management and restoration to improve the conservation status of Natura 2000 habitats and species, and/or reduce flood risks; conversion of arable land to grassland to reduce the risk of soil erosion; management of existing agro-forestry systems for biodiversity and landscape conservation.

Delays and risk averse behaviour in CAP implementation

The division of responsibilities for climate action between several government departments is not unusual in Member States and requires carefully co-ordinated timing of policy decisions and the introduction of new support schemes which can be difficult to achieve in practice. For example, in one Member State committed to increasing energy generation from biomass there is an agricultural investment scheme already in place to support cultivation of short-rotation coppice and *Miscanthus*, but farmers are reported to be delaying planting biomass crops until the national energy ministry launches a Renewable Heat Incentive scheme (pers.comm).

For many of the RDP land management measures used by Member States there is an unavoidable roll-over of contracts for farmers and committed expenditure from one programming period to the next, which can have a significant effect on the availability of financial and technical resources for new measures. Examples include continuing or renewed multi-annual contracts or investment support for agri-environment, forest management, non-productive investments, forest investment and afforestation.

There is often a time lag in widespread implementation of new CAP measures, at the beginning of a new programming period, especially where these are not obligatory. Typically a few Member States are early adopters in the first programming period, while others are more cautious. In some cases there may be technical reasons for the delays, for example a lack of clearly defined or widely applicable baselines for new types of support payments. Also, for managing authorities with limited time and staff resources to set up the new CAP, there is an understandable tendency to continue with existing measures where these ‘fit’ the reformed CAP measures, especially when there are new, more detailed implementation rules and reporting requirements for new measures, as happened in 2014. This could inhibit the introduction of more novel climate measures in many Member States. This means there may be considerable delay in uptake of unfamiliar actions, or those not previously supported by the Member State such as the RDP measure for new agro-forestry, or the use of non-productive investments for planting hedges. Where the action may be cost-effective for the farmer and but can only be supported by CAP ‘soft’ measures the response by Member States may be quicker because it requires adjustments to existing plans such as those for advisory services and EIP operational groups, rather than introducing new schemes. However the uptake of these actions (for example carbon audits, improved N efficiency, improved on-farm energy efficiency and use of sexed semen) depends on farmers’ response to the ‘soft measures.

Following recent criticism from the EU Court of Auditors on the verifiability of land management measures within the RDP, the Commission guidance on control and verification has been strengthened, especially for measures that require field inspections or are difficult to verify, such as conditions affecting fertilizer usage or stocking rates. Managing authorities are understandably concerned to avoid disallowance for errors in CAP expenditure, and for the first time Member State paying agencies have had to ‘sign off’ all RDP measures as verifiable for the 2014 to 2020 RDPs. This, coupled with efforts to achieve cost efficiencies, has made them more risk averse and there are anecdotal reports that this has limited the scope or enthusiasm for Member States to use some measures, including existing agri-environment schemes. This may have some knock-on impacts for certain climate mitigation actions, such as those involving improved nutrient management such as the implementation of soil and nutrient management plans, improved N efficiency, improved on farm energy efficiency, livestock disease management and biological N fixation.

Path dependency and constraints arising from broader decisions on the use of CAP policy tools

The implementation and uptake of some CAP climate mitigation measures in the present period (2014 to 2020) can depend on decisions made by managing authorities earlier in the process of CAP implementation. Such decisions include the definition of ‘agricultural area’ and ‘permanent grassland’; the eligibility of pastureland with trees; and the coherence of related GAEC standards, EFA definitions and agri-environment-climate measures. Used constructively and coherently these measures can encourage farmers to protect the carbon sequestration potential of their land. Negative consequences for climate mitigation arise where the cumulative effect of these decisions at farm level creates a perverse incentive for farmers to remove trees and shrubs in order to qualify for CAP income support payments. For example, there is new evidence that wood pastures in Spain which were eligible for payments in 2007 to 2013 have been excluded from the CAP Basic Payment Scheme in 2015[60]; the reason are unclear but one possible explanation is political pressure to minimise the redistribution of income support payments between farms of different types which ensues from the conversion of 'historic' Single Payment Scheme to 'regional' Basic Payment Scheme. In other Member States the requirement to exclude from the eligible area Pillar 1 payments the pastureland under the crown of in-field trees (rather than just the area occupied by the stem of the tree) is a perverse incentive to remove or limit the growth of farmland trees. These are just two examples of decisions on CAP implementation which have already been made for the 2014 to 2020 period, where the cumulative effect at farm level could prove to be a *disincentive* for farmers to prevent deforestation and to manage existing trees and other 'woody' features on farmland in many Member States.

The positive choices (in this sense) that managing authorities can choose to make when defining national or regional CAP rules include the following, which will provide farmers with a range of incentives to protect carbon sequestration resources:

- if managing authorities define cross-compliance requirements for woody landscape features, ditches and ponds under GAEC 7 then such features can qualify as EFAs under greening requirements.
- there is scope to define EFAs in the form of 'equivalent' agri-environment-climate commitments, with payment rates reduced accordingly
- if managing authorities choose to offer new agroforestry and afforestation of farmland as EFA options, then farmers have the incentive that these two climate mitigation actions can count towards their EFA obligations and are eligible for the full rate of RDP support
- managing authorities can, if they choose to do so, ensure that farmland land with scattered trees, shrubs or woody landscape features are eligible for CAP income support payments. They have several options. Landscape features such as hedges are eligible if regarded as part of local good agricultural practice and/or defined under GAEC 7; land with scattered trees is eligible if there are no more than 100 trees per hectare and it can be farmed in a similar way to parcels without trees. There is an alternative option for permanent grassland - if the trees and other features do not constitute more than 10% of the area the whole parcel is eligible, and if more than 10% the eligible area is reduced pro rata[61].

One way to overcome these issues is to encourage EU level sharing of best practices of how the CAP has been used to support climate mitigation actions in different regions of the EU, for example via the European Network for Rural Development's Contact Point. Pilot projects could also be initiated and encouraged in in Member States to demonstrate innovative ways to improve the efficient and effective use of CAP support for climate mitigation purposes. Member States could be encouraged to use the CAP cooperation measure to implement pilots, or this could be promoted at EU level, for example as with the currently funded EU-wide pilot projects for results-based payment schemes funded by the European Parliament and coordinated by DG Environment[62].

[60] It is reported that for 2015 managing authorities in Spain have reclassified as forest many LPIS pastures with trees/shrubs where active grazing is the main use, making these ineligible for CAP income support payments; the authorities' guidance states explicitly that the farming use of the parcel should not be taken into account in this process (Ruiz and Beaufoy, 2015).
[61] Articles 9 and 10 of Commission Delegated Regulation (EU) 640/2014
[62] See for example: http://ec.europa.eu/environment/funding/pdf/rbaps/EP%20Pilot%20grant%20RBAPS%20call.pdf

Deciding whether to choose CAP policy tools or other sources of financial support

A few managing authorities have decided to opt out of key elements of CAP support for climate mitigation actions. For example, in Germany the city region of Hamburg has decided 'for reasons of efficiency' to implement its whole RDP without EAFRD co-financing, which has consequently required 'a reorientation of measures for rural development)[63]. This is exceptional. However, Ireland has chosen a demanding target for afforestation to contribute to its emissions targets (8,000 ha per year of new planting on farmland until 2020). Yet despite this ambitious target Ireland has decided that its afforestation measure this will not be co-financed by EAFRD for reasons that are reported to include 'the EAFRD rules'. It is understood that the German region of Bavaria will also implement its afforestation programme without EAFRD co-financing. This may be a reaction in part to the more rigorous environmental requirements applied to the afforestation measure for 2014 to 2020.

The introduction of the 2014-20 CAP required Member States to make major policy choices in a very short time span. In addition to the implementation guidance in Regulations published in 2014 the Commission has produced detailed guidance fiches and other documents, and responded to specific implementation questions from Member States[64]. However, one of the experts interviewed for this project commented on the problems in accessing Commission guidance. For example the draft guidance and specific fiches on mainstreaming climate change in the CAP were provided only in English for the 21 regional managing authorities in Italy, with just a short article in Italian in the RDP national newsletter. It is possible that Member States authorities may have considered more innovative climate measures if they had had a longer period of time to do so. More innovative measures could be introduced over time as successful examples from other Member States become available.

Potential under-representation of climate mitigation actions in formal CAP monitoring and reporting processes

It was suggested by one of the experts interviewed that the new requirements for clarity of policy focus in the 2014-20 RDPs may lead to the 'invisibility' of the climate mitigation benefits of some RDP measures. For example, many agri-environment-climate schemes targeted at other environmental objectives (e.g. biodiversity conservation, reducing risks of soil erosion) also have significant benefits for climate mitigation. If the Member State/region has allocated the benefits under separate objectives linked to different priorities and focus areas within the RDP, there is an obligation to measure CMEF indicators related to each of the objectives. However if they link the objective to only one priority/focus area and that is not climate mitigation, then the climate benefits may be very real, but may not feature in the RDP monitoring and evaluation reports. Hence under-representation of the climate mitigation effect of the measure may be a significant issue.

However, there are also other questions about how Member Sates decide to classify and report measures in relation to their formal objectives. A study of the methodological frameworks used to evaluate environmental impacts in twenty of the 2007 to 2013 RDPs found that 30 EAFRD measures were reported by regions as being relevant for climate change mitigation, but causal relationships between the measure and the mitigation effect were identified for only 15 measures, of which seven were forest measures (Smyrniotopoulou and Vlahos, 2013).

To address this, ways need to be found within the CAP's Common Monitoring and Evaluation Framework (CMEF) to formally recognise and report on the many climate mitigation effects that are secondary benefits of measures used primarily to address other environmental objectives on farm and forest land, such as mitigating risks of soil erosion or diffuse pollution, creating or restoring wildlife habitats, growing biomass for renewable energy. This would help

---

[63] *Anlage I zur Senatsdrucksache Nr. 2015/ 202 Agrarförderprogramm 2015 – 2020* [Annex I to Senate document no. 2015/202, Agricultural support program 2015 – 2020] http://www.hamburg.de/contentblob/4455742/data/agrarfoerderprogramm-2015-2020-der-fhh.pdf
[64] European Commission (2015)

generate a clearer sense of the potential climate mitigation reach and subsequent impact of all CAP measures (as well as other EU funds) even where the primary objective of the intervention is not climate mitigation (see examples in chapter 3). In addition, it would help if more robust methodologies for the reporting of climate mitigation actions and guidance could be developed for Member States to use to evaluate the effectiveness of climate mitigation actions on the ground.

Gaps in knowledge, methodologies and data required for climate mitigation reporting

Many Member States are having to address problems of availability of the data they require for climate reporting, and in some federal Member State there are also issues of coherence of data sets and methodologies between different regions.

Member States that have elected to report on cropland management and grassland management for the second KP period require accurate emissions factors and spatial land use data for these land uses. There is a reasonable understanding of cropland emissions but there are still some gaps reported in the availability of activity data and emissions factors for livestock systems and grasslands, for example on manure storage, nitrogen use and cattle kept outdoors (where it is more difficult to control dietary intake and hence CH4, N_2O and NH_3 emissions). The precise nature and significance of data gaps will of course differ depending on the circumstances in a particular Member State. In Ireland, for example, where there is a temperate climate and predominance of grassland on C-rich soils there is a judgement to be made at farm level between the merits of draining the land and losing CO_2 as a consequence, or not draining but using fertilizer and increasing N_2O emissions in order to meet yield objectives. The lack of information on emissions from organic soils here has been a barrier, but a network of researchers in Ireland is looking at emissions from agricultural soils and the government research and advisory agency TEAGASC is working on an Irish Soil Information System.

Other potential barriers to improving the scientific and practical knowledge needed to improve the uptake of climate mitigation actions at farm level include the time required to form effective networks between researchers and farmers, the difficulties that may be encountered and the lack of economic (and social) data on farmers' motivation to take action on climate mitigation. The newly formed Operational Groups that have been introduced in Member States as part of the European Innovation Partnership for sustainable agriculture should help facilitate these links going forward. Joint research projects actively involving researchers and farmers on how to improve the uptake of climate mitigation actions in practice would also be useful, something that could be funded via both the EIP and Horizon 2020.

One frequently mentioned problem is that IACS and LPIS, which are critical CAP data sources, provide fine-grained land use data, annually updated, but the potential of this resource for climate reporting is vastly underused. There are a number of different issues. Access to IACS data is restricted in many Member States due to concerns about privacy issues, and Member States are obliged to delete IACS data after 10 years, which means that valuable land use information pre-dating 2005 has been lost. The paying agencies collect and manage IACS data for the specific purpose of verifying and controlling CAP expenditure. They do not have the remit or resources to collect and analyse additional data for climate purposes, and some are unwilling to share data with climate authorities (or even RDP evaluators).

A recent assessment of the availability of current and potential data sources for climate reporting and accounting for crop and grassland management (Freibauer *et al.*, 2015) made a detailed assessment of LPIS data and found that:

- LPIS does not cover all land in agricultural use, just the land for which CAP payments are claimed, which means that there are particularly large gaps in the coverage of extensive grassland systems.
- LPIS data are not consistent with other data sources and LPIS data is not reliable in a non-spatially explicit mode.

- Even in spatially explicit mode LPIS data requires adjustments for climate reporting because LPIS objects are not stable over time due to changes in boundaries and ownership and intermittent recording when parcels are not subject to CAP payment claims.
- In some Member States or regions the reference system of LPIS does not reflect accurately the land cover within a single agricultural parcel if this comprises several differently cropped units. This means that the system cannot be used to distinguish cropland from grassland and does not allow land-use changes to be tracked over time.

The level and type of data gathered in IACS varies from one Member State to another and there are some rather specific challenges. For example in federal Member States there can be problems of co-ordinating regional IACS data. For example, in Germany a combination of EU and national data rules means that IACS data (and the LPIS GIS layer which would be useful to integrate with soil data) cannot be used for LULUCF accounting.

However, at least eight Member States, including some with a federal structure, do use LPIS data in various ways for reporting cropland management or cropland to grassland conversion, as shown in Table 66.

Table 66: Information from IACS/LPIS used by Member States for climate reporting

Member State	Information obtained from IACS/LPIS[65]
BE	Use of LPIS in a statistical way
FI	Land conversion data
	Crop statistics used for C stock change modelling for mineral soils and for calculating the proportions of annual and perennial crops grown on organic soils
AT	Land conversion data
	Estimation of cropland management factors and land management information
DK	Data on crops grown on fields and soil level (used for a new soil map of mineral and organic soils), subdivided into cropland and permanent grassland
IE	To establish statistical probabilities of soil types associated with cropland and grassland.
	To verify the assumption that burning is not a management practice on cropland in Ireland.
FR	Data of 'Registre parcellaire graphique'
BG	Balance of physical blocks in permanent agricultural use and balance of ownership areas
SE	Crop harvest data
Source: (Freibauer *et al.*, 2015)	

As noted above, making more effective use of LPIS/IACS, extending its capacity to reflect the rapid and continuous transformations that take place on agricultural land in consistent time series would undoubtedly improve the synergies between NIR and CAP reporting by

[65] Not all countries using LPIS indicated what kind of data they used.

This would require, *inter alia*:

- spatially explicit recording of changes in land cover on LPIS, and of land used to claim direct payments, permanent grassland, EFA features parcels within RDP land management support relevant to climate change; and full access to this data for both inventory agencies and RDP evaluators. For example, Ireland has resolved privacy issues through the careful preparation of an anonymous data product and the terms in the Memorandum of Understanding between the agricultural administration and the inventory agency (Freibauer *et al.*, 2015);
- recording on LPIS of all land in agricultural use, whether or not it is used to claim CAP payments in the year of recording;
- harmonising of LPIS/IACS time series updating to facilitate data transfer to NIR reporting (in the longer term if harmonisation and standardisation at pan-European level was realised, LPIS/IACS could be the primary basis for National Spatial Data Infrastructure in the EU;
- retaining geo-referenced IACS data for the long term, properly archived; and
- amending the legislation on LPIS/IACS to reflect this repurposing of IACS and allocating additional resources to paying agencies to improve and maintain data systems for the benefit of climate reporting.

6.3 Barriers at farm level

It is important to recognise that the uptake of climate mitigation actions by individual land managers is influenced by many factors, including the costs of implementation and other impacts on the farm business, technological and socio-cultural constraints, lack of awareness and knowledge of the reasons for taking action and its consequences as well as the shortfalls in the availability of and advice on the implementation of the action; and the absence of tangible individual benefits of the action and concerns about potential risks.

Implementation costs and business impact

It is clear that the costs of the different climate mitigation actions vary greatly depending on the types of activity involved, the extent to which they entail departures from current or likely future agricultural practice, and the degree to which new investment is required or opportunity costs arise. There is very limited data on these costs, especially at EU level. The type of costs involved are identified for each of the climate mitigation actions, in chapter 3), with examples of costs or savings where available, but these are only illustrative, not representative of costs across the EU. What they do appear to show, however, from the limited information available, is that there can be a large range of variation in costs/benefits for some of the actions.

Table 67 summarises for all the climate mitigation actions covered in the report what types of the potential savings and costs are likely to be involved. Where changes are made within an existing crop or livestock system the balance between net savings and net costs will differ from one farm to another, and can only be identified at farm level. Opportunity and investment costs, as might be expected, are associated with significant changes in land use, although these changes may in the longer term bring benefits from an alternative income stream.

In seeking to improve uptake of climate mitigation actions it will be very important to provide farmers with the capacity to make or acquire realistic assessments of the economic effect of the action in their particular circumstances.

Table 67: Potential savings and costs to farmers and foresters of implementation of climate mitigation actions

CLIMATE MITIGATION ACTION	POTENTIAL SAVINGS	POTENTIAL COSTS		
	Net savings and/or improved efficiency or productivity	**Net cost/ income foregone**	**Investment costs**	**Opportunity costs of change in land use**
Land Use				
Conversion of arable land to grassland to sequester carbon in the soil		yes	possibly	yes
Agroforestry	possibly, depending on changes in productivity of crops/grassland/trees	possibly, depending on changes in productivity of crops/grassland/trees	yes	yes
Wetland/peatland conservation/ restoration	possibly, if market for paludiculture crops or carbon	on potentially productive peat soils	yes	on potentially productive peat soils
Woodland planting	possible farm efficiency gains	possibly	yes	yes
Preventing deforestation and removal of farmland trees		possibly but likely to be low		
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	possibly	possibly	possibly	
Crop Production Systems				
Reduced tillage	possibly	possibly		
Zero tillage	possibly	possibly	possibly	
Leaving crop residues on the soil surface		possibly if selling residues		
Ceasing to burn crop residues and vegetation	possibly if local market for residues			
Use cover/catch crops	possibly, depending on current cropping	possibly, depending on current cropping		
Livestock Production Systems				
Livestock disease management	possibly depending on cost of interventions	possibly depending on cost of interventions		
Use of sexed semen for breeding dairy replacements	possibly depending on current herd management			
Breeding lower methane emissions in ruminants	no information	no information	no information	
Feed additives for ruminant diets		yes		
Optimised feeding strategies for livestock	possibly	possibly		
Manure, Fertilizer & Soil management				
Soil and nutrient management plans	possibly, depending on balance of costs/savings in making and implementing plans	possibly, depending on balance of costs/savings in making and implementing plans		
Use of nitrification inhibitors		yes		
Improved nitrogen efficiency	possibly, depending on balance of costs/savings in making and implementing plans	possibly, depending on balance of costs/savings in making and implementing plans		
Biological N fixation in rotations and in grass mixes	possibly, depending on current cropping	possibly, depending on current cropping		
Energy				
Carbon auditing tools	possibly, depending on actions required to implement improvements	possibly, depending on actions required to implement improvements	possibly, depending on actions required to implement improvements	
Improved on-farm energy efficiency	possibly, depending on actions required to implement improvements	possibly, depending on actions required to implement improvements	possibly, depending on actions required to implement improvements	

Technical constraints

The review of land use actions (e.g. conversion of arable to grassland, woodland planting or wetland/peatland conservation and restoration) highlighted no technical constraints to implementation but there may be an over estimation of the knowledge of some farmers in this area, for example in new agroforestry systems which are unfamiliar to many farmers and their advisers. For these actions, therefore, there is likely to be a requirement for advice and training to maximise the climate benefits of land use changes.

With crop production actions (e.g. use of cover/catch crops/ zero tillage), most are fairly well understood in terms of field level techniques and no technical advancement is required, but the farmers are likely to need advice appropriate for their specific circumstances (e.g. soil types, water availability, existing rotation) to be able to implement some of the actions effectively for the climate and for their business.

Actions relating to livestock production are more mixed in terms of requirements for improved technology and understanding. For example, the use of feed additives and breeding lower methane ruminant animals requires further technological advancement before widespread implementation could be achieved, and virtually all of the livestock actions require some degree of training to realise the benefits.

Manure, fertilizer and soil management actions are generally uninhibited by technological constraints although farmers may need technical support for some actions (e.g. soil testing for nutrient management planning). Energy efficiency actions are generally well understood although farmers may not be aware of the potential benefits.

Provision of awareness, knowledge and advice

The evidence on the greenhouse gas mitigation potential of different types of farm and forest management is evolving all the time and it is therefore a challenge to ensure that farmers and foresters are aware of the effects of different types of management on greenhouse gas emissions. The lack of knowledge and technical skills is identified as a barrier to uptake of some climate mitigation actions in a number of studies (for example: Feliciano *et al.,* 2014; Kim and Neff, 2009). This is particularly true of those who do not use specialist financial and technical advisers. In addition, information provision by relevant governmental or private bodies may be in limited supply or aimed at a limited segment of the farm population. Labarthe and Laurent (2009) noted that better educated and trained farm managers are more likely to make successful changes to farm-management practices and become more innovative and flexible. In the EU a particular concern is the problem of small farmers and foresters, who are, as a group, important contributors to reducing greenhouse gas emissions, but have little or no access to the relevant extension services (Keenleyside *et al.,* 2012). Smaller and less intensively managed farms as well as those with less-well educated and/or older farmers and poor access to web-based information are particularly likely to 'fall below the radar' of both commercial (e.g. agro-chemical and feed suppliers) and government (e.g. the Farm Advisory System) advice and information services.

In providing advice and information to farmers on climate mitigation actions, the framing of the advisory message can be as important as the content. For example, the concept and mitigation purpose of increasing soil carbon is difficult to communicate to farmers, but they more readily understand that increasing soil organic matter usually improves the fertility of the soil.

Awareness and understanding of climate mitigation actions could be improved among both farmers and advisers by using not just existing advisory services but also cooperation projects, demonstration and training opportunities.

Visibility of tangible benefits and concerns about potential risks

The lack of visibility of climate benefits can also sometimes be a barrier to uptake of climate mitigation actions, because GHG emission reductions are not evident on the ground in the same way as many other forms of environmental land management, such as semi-natural habitat management and creation. This means that farmers have nothing to show for improvements to soil organic matter, or reduced NH_3 and CH_4 emissions from manure storage, nor can they enjoy these benefits personally, as they might if they were to carry out management to increase numbers of farmland birds or butterflies, or restore hedges and stonewalls. Farmers may be very reluctant to take the risk of changing established cropping patterns, farming/forest production systems and land use if these are perceived to work well for their business, even where sufficient advice, training and evidence is available.

6.4 Conclusions for policy and the future CAP

There are a number of conclusions that can be drawn from this analysis regarding any policy changes that might be required to enhance uptake of the climate mitigation actions with highest climate mitigation potential.

Although data were not available in the public domain to enable an assessment in this study of the current uptake or impact of the majority of the actions examined here in different Member States, it is clear that additional effort is needed to reduce GHG emissions and increase removals in all Member States if the agricultural sector is to increase its contribution to existing and future GHG emission reduction targets. This means that climate mitigation actions should increasingly be a focus of implementation choices made by Member State and regional authorities.

As highlighted in the section above, most of the policy tools required to incentivise greater uptake of climate mitigation actions are already available via the CAP. The issue, therefore, is more to do with the way in which Member States choose to implement (or not) these policy tools, and how they design the detailed rules, definitions and support measures.

As well as policy measures that provide financial support to farmers to encourage greater use of climate mitigation actions, soft measures, e.g. advice, knowledge transfer and training are also critical to encourage optimal levels of uptake of the right actions in the right locations. Indeed, once policy measures have been chosen and designed to contain those actions that can enhance mitigation potential, the benefits of these actions to the beneficiaries themselves (not just wider society) must be well communicated to encourage uptake of the right actions in the right locations. It is currently optional for Member States to provide information via the Farm Advisory Service information on: GHG emissions of different farming practices; the contribution of the agricultural sector to mitigation through improved farming and agroforestry practices; and how to improve and optimise soil carbon levels. It would be extremely beneficial if the provision of advice on these topics, particularly in relation to those climate mitigation actions identified as having the greatest mitigation potential in each Member State were made compulsory for Member States.

To ensure that the role policy plays in encouraging climate mitigation efforts are recognised and that climate impacts are better reported, ways need to be found within the CAP's Common Monitoring and Evaluation Framework (CMEF) to reflect the climate mitigation effects of all CAP measures (as well as other EU funds) even where the primary objective of the intervention may not be climate mitigation. Member States also must put robust data collection and monitoring processes in place to allow for this, as well as to enable accurate and compliant reporting through NIRs. Requirements for reporting and monitoring for NIRs and policy implementation must be considered together and tools and data shared for a more streamlined and cost-efficient process.

Nonetheless there are a few areas where the CAP legislation and related processes could be improved or the rules and Commission guidance to Member States on implementation strengthened to enhance the climate mitigation potential of certain measures. A number of examples are highlighted here, some of which may be feasible to 2020, although the majority would require changes to the basic legislative acts and would need to await a further CAP reform.

For example, the protection of carbon rich soils remains a priority where they occur, both through preventing the ploughing of those soils already under permanent grassland and minimising further losses of carbon from cultivated carbon rich soils. Agreement on the definition of a carbon rich soil would first be required. However, assuming this were feasible, the policy focus on high carbon soils could be increased in a number of ways. For soils those under permanent grassland the greening rules for maintaining permanent grassland could be strengthened by:

- introducing farm level authorisation procedures as is already the case in some countries such as Germany but requiring that Member States do not permit ploughing on carbon rich soils.;
- requiring that carbon rich soils under grassland in Natura 2000 areas are designated as Environmentally Sensitive Permanent Grassland; and
- making it compulsory for Member States to designate carbon rich soils under grassland outside Natura 2000 areas.

On arable soils, the implementation of EFAs could be tailored to minimise losses of soil organic carbon, for example by encouraging the use of cover crops, putting buffer strips in place or land under fallow or by requiring Member States to offer these options to farmers by making these EFA elements obligatory in all countries. In the short term, to 2020, Member States could be encouraged to develop equivalence schemes with this aim in mind, for example. The weakness of trying to tailor the EFA approach for this purpose is that it is currently not possible to influence where farmers implement the options at field level and it is difficult to see how this could be introduced in a Pillar 1 scheme. There may be scope for developing more advanced linkages between Pillar 1 and Pillar 2 measures to increase the feasibility of targeting. A further possibility could be to propose the introduction of a new GAEC standard under cross-compliance that would help protect carbon rich soils – by preventing the ploughing of carbon rich permanent grasslands and requiring certain soil management activities on carbon rich arable soils (e.g. fallow, buffers, catch crops).

Rural development policy and actions within regional RDPs will continue to be essential for protecting as well as restoring carbon rich soils. For example, building on existing good practice, emphasis should continue to be placed on the use of the agri-environment-climate measure to maintain and restore peatland and wetland areas.

To reduce GHG emissions more generally, the design and implementation of EFAs could be altered to enhance their climate mitigation potential. For example, the measures available could be offered in packages or combinations that were considered to deliver the most for climate mitigation. This could be achieved in the short term via equivalence schemes. Equivalence schemes could also be introduced for the crop diversification, particularly under the agri-environment-climate measure, to require crop rotations and for legumes, catch crops and/or fallow to form part of these rotations. Strengthening the rules for the maintenance of permanent grassland would also apply here, particularly the shift towards its application at farm level, in the short term by revising authorisation procedures to apply on a case by case basis.

The evidence in chapter 3 has shown that measures to promote woodland planting and the introduction of new agro-forestry systems via Pillar 2 has been very low to date, despite having high mitigation potential in the majority of Member States. The benefits of agroforestry systems for climate mitigation (and other environmental and production benefits) are becoming increasingly clear and Member States are becoming increasingly interested in the value of these systems. The multiple benefits should be communicated more widely amongst relevant stakeholders and potential beneficiaries and higher levels of funding allocated to the RDP measure to promote agro-forestry systems more widely in the EU. More generally, it would be very beneficial to encourage greater EU level sharing of best practices of how the CAP has been used to support climate mitigation actions in different regions of the EU, for example via the European Network for Rural Development's Contact Point. Pilot projects could also be initiated and encouraged in in Member States to demonstrate innovative ways to improve the efficient and effective use of CAP support for climate mitigation purposes.

Despite many of the livestock mitigation actions (e.g. disease management, use of feed additives being difficult to quantify and appearing to have minimal impact on total emissions, there may be merit in incentivising actions on the basis of carbon efficiency and there are examples of Member State initiatives to address endemic disease such as Bovine Viral Diarrhoea (BVD), Jonnes and combatting anthelmintic resistance for treatment of parasites, which will all lead to production efficiencies and as a result improve the carbon intensity of production. Although not specifically related to the climate mitigation actions identified as being of high priority in this study, the RDP in Ireland for 2014 to 2020 is providing support to livestock farmers to record various genetic traits and characteristics of their suckler herds to be input into a meta database. The hope is that this will over time inform breeding programmes to improve herd productivity and therefore reduce GHG emissions per animal. The challenge is that the impact on absolute emissions could be minimal as the likely result is market driven rather than having a direct impact on emissions.

It may be possible to use the newly formed Operational Groups that have been introduced in Member States as part of the European Innovation Partnership for sustainable agriculture to promote greater links between researchers and farmers, which in turn could lead to more innovative approaches and uptake of climate mitigation actions. Joint research projects actively involving researchers and farmers on how to improve the uptake of climate mitigation actions in practice would also be useful, something that could be funded via both the EIP and Horizon 2020.

Finally, there are some climate mitigation actions which would require some form of incentive to encourage their widespread uptake, but where the CAP is not necessarily the optimal policy mechanism for doing so. The use of nitrification inhibitors in fertilizers are a good example of this kind of action. Although their use could be made a requirement of agri-environment-climate schemes, in theory more widespread uptake would be made possible if fertilizer manufacturers were required to include nitrification inhibitors within all N fertilizers sold in the EU over a set timeframe. This could be something to be considered in the forthcoming review of the fertilizers regulation.

6.5 References

European Commission (2015) Management Plan 2015: Directorate-General for Agriculture and Rural Development. Ref. Ares (2015)4343251 - 16/10/2015.

Feliciano, D., Hunter, C., Slee, B. and Smith, P. (2013) Selecting land-based mitigation practices to reduce GHG emissions from the rural land use sector: A case study of North East Scotland, Journal of Environmental Management, 120, 93-104.

Freibauer A, Gensior A, Hart K, Korder N, Moosmann L, Schmid C, Schwaiger E, Schwarzl B, Weiss P (2015), Guidance on reporting and accounting for cropland and grassland management in accordance with Article 3(2) of EU Decision 529/2013/EU, Task 3 of a study for DG Climate Action: 'LULUCF implementation guidelines and policy options', Contract No CLIMA.A2/2013/AF3338, Institute for European Environmental Policy, London.

Hart K, Baldock D, Tucker G, Allen B, Calatrava J, Black H, Newman S, Baulcomb C, McCracken D, Gantioler S (2011) Costing the Environmental Needs Related to Rural Land Management, Report Prepared for DG Environment, Contract No ENV.F.1/ETU/2010/0019r. Institute for European Environmental Policy, London.

Keenleyside C, Menadue H and Baldock D (2012) 'Soft' measures within agri-environmental policy; a report prepared for the OECD. Institute for European Environmental Policy, London.

Kim, B. and Neff, R. (2009) Measurement and communication of greenhouse gas emissions from U.S. food consumption via carbon calculators. Ecological Economics. 69, 186-196.

Labarthe P and Laurent C. (2009) Transformations of agricultural extension services in the EU: towards a lack of adequate knowledge for small-scale farms. Paper presented at the 111

EAAE-IAAE seminar "Small farms: decline or persistence, University of Kent 26-27 June 2009. http://ageconsearch.umn.edu/bitstream/52859/2/103.pdf

Ruiz, J and Beaufoy, G (eds) (2015) Informe sobre la elegibilidad para pagos directos de la PAC de los pastos leñosos españoles. Plataforma por la Ganadería Extensiva y el Pastoralismo.

Smyrniotopoulou, A and Vlahos, G (2013) Summary report on the review of indicator sets and monitoring approaches. ENVIEVAL: Development and application of new methodological frameworks for the evaluation of environmental impacts of rural development programmes in the EU KBBE.2012.1.4-08 http://www.envieval.eu/fileadmin/redaktion/Dissemination/Deliverables/D2_1_final_revised_May_2014.pdf

Swinnen J ed (2015)The Political Economy of the 2014-2020 Common Agricultural Policy: An Imperfect Storm, Centre for European Policy Studies (CEPS), Brussels, Rowman and Littlefield International, London.

Underwood, E.1; Poláková, J.1; Berman, S.3; Dooley,E.2; Frelih-Larsen, A.2; Kretschmer, B.1; Maxted, N.5; McConville, A.J.1; Naumann, S.2; Sarteel, M.3; Tostivint, C.3; Tucker, G.M.1; van der Grijp, N.M.4 (2013) Technology options for feeding 10 billion people. Climate change and agriculture; biodiversity and agriculture. Report prepared for the STOA Panel of the European Parliament. Contract IP/A/STOA/FWC/2008- 096/LOT3/C1/SC5. Institute for European Environmental Policy, BIO Intelligence Service, Ecologic Institute, IVM, Brussels/London.

7 Conclusions

This section summarises the key outputs of this study in terms of the climate mitigation potential of the range of mitigation actions reviewed for different regions in the EU-28 and the opportunities for and barriers to their increased implementation. It concludes with a summary of key messages.

7.1 Outputs

The main outputs of this work are listed in Table 68, together with their locations in this report and its annexes. The outputs contain much inter-related information, and this is summarised for each MA in Section 3 (Analysis of mitigation actions).

Table 68: List of outputs and location in report

Outputs	Report location
List of MAs	Table 2, Section 2
Fiches for each MA	Annex 1
Multi-criteria assessment for each MA	Section 3 Analysis of mitigation actions
Maps to illustrate mitigation potential by MS or NUTS 2 area	Section 3 Analysis of mitigation actions
Maps to illustrate applicability across the EU	Section 3 Analysis of mitigation actions
Mitigation potential values	Section below and electronic spreadsheet provided to the EC with this report: “ED60006 Mitigation potential FINAL”
Analysis of National Inventory Reports and reporting categories	The results are provided in a spreadsheet format (ED60006 category Analysis FINAL), with a summary for each MA presented in Section 3 of this report.
Identification of policy measures to support implementation of climate mitigation actions	The results are provided in a consolidated in Annex 5, with a summary for each MA presented in Section 3 of this report
Additional administrative effort required to implement climate mitigation actions	Section 4 of this report, with tables of costs set out in Annex 4
Overcoming barriers to implementation of climate mitigation actions	Section 6 of this report
Key messages	This section, below
Workshop 1 March 2015	Annex 6
Workshop 2 September 2015	Annex 7
LILUCF consultation summary report	Annex 8

7.2 Workshops

Workshop 1: Promoting climate mitigation on agriculture and forest land

This workshop took place on March 6th 2015. The focus of the event was to review effectiveness of mitigation actions, policy tools and implementation strategies. Presentations were provided by the project team on the screening activity and potential mechanisms for implementation. Breakout sessions provided opportunities for feedback and insights from MSs and NGOs on experiences of reviewing and implementing actions and views on the effectiveness of mitigation actions.

The event was well attended with 69 delegates and feedback was positive. A full report can be found in Annex 5.

Workshop 2: Agriculture and LULUCF in 2030 EU Climate and Energy Framework

The second workshop was held on the 14th & 15th September with the primary objective to provide feedback on the consultation on addressing greenhouse gas emissions from agriculture and LULUCF in the context of the 2030 EU climate and energy framework.

Day 1 was led by the Commission and included a summary of consultation responses which was followed by a panel discussion involving high level industry stakeholder speakers debating the contribution of agriculture and other land use sectors in GHG emissions abatement. Breakout groups, facilitated by the Ricardo and IEEP team were held to get the views of delegates on the challenges of implementing mitigation activity for the agriculture and land use sectors. Summaries of sessions were provided by senior commission representatives.

Day 2 provided an opportunity to summarise the findings of reports undertaken recently on behalf of DG CLIMA. Presentations were given by the Ecologic Institute, Ricardo and IEEP.

152 delegates attended Day 1 and 138 attended day 2. A full report can be found in Annex 6.

7.3 Mitigation potential

To help comparison between mitigation actions and their mitigation potential values, we present bar charts (Figure 69, Figure 70, Figure 71, Figure 72 and Figure 73), using groups of mitigation actions as in Table 69. Each of these figures comprises two bar charts: a) mitigation potential (kt CO_2e per year, for the EU28) per percentage point of uptake; and b) mitigation potential (kt CO_2e per year, for the EU28) calculated using estimates of likely uptake as presented in Chapter 4 .All of the bar charts labelled a) use consistent axis scales (0 to 7,000), and all of the bar charts labelled b) use common axis scales (0 to 70,000); this is to help comparison between charts.

Table 69: Groupings of mitigation actions

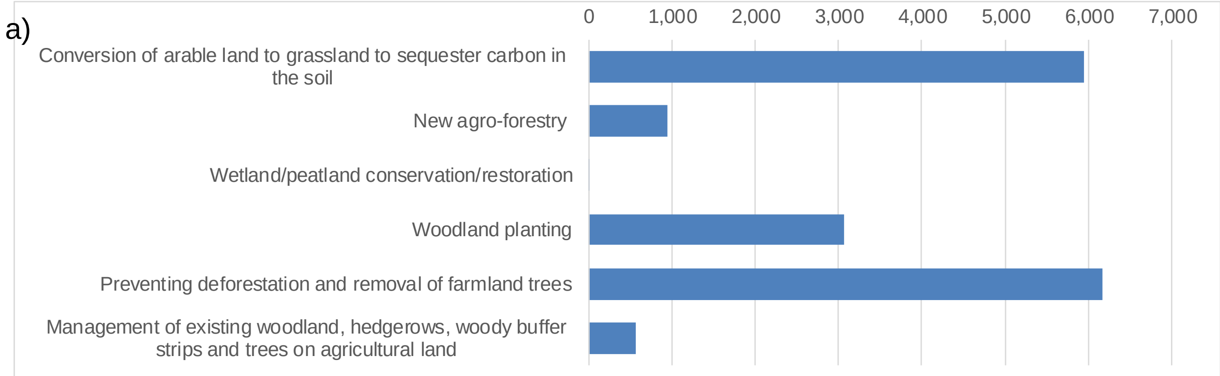
Group	Mitigation actions
Land Use	• Conversion of arable land to grassland to sequester carbon in the soil • New agroforestry • Wetland/peatland conservation/restoration • Woodland planting • Preventing deforestation and removal of farmland trees • Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land
Crop Production	• Reduced Tillage • Zero Tillage • Leaving crop residues on the soil surface • Ceasing to burn crop residues and vegetation • Use cover/catch crops
Livestock Production	• Livestock disease management • Use of sexed semen for breeding dairy replacements • Breeding lower methane emissions in ruminants • Feed additives for ruminant diets • Optimised feeding strategies for livestock
Nutrient and Soil management	• Soil and nutrient management plans • Use of nitrification inhibitors • Improved nitrogen efficiency • Biological N fixation in rotations and in grass mixes
Energy	• Carbon auditing tools • Improved on-farm energy efficiency

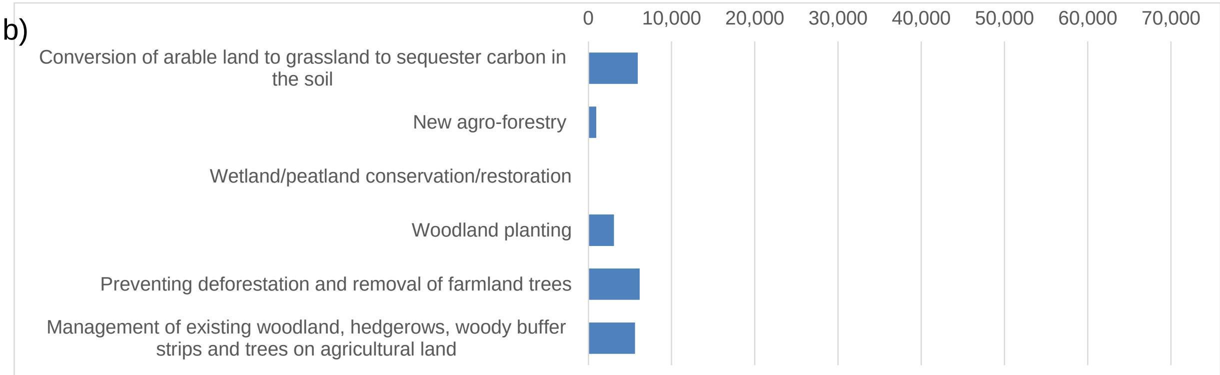
In Figure 69 the mitigation potential values at EU level are shown, for MAs that involve land use change, prevention of land use change, or management of landscape features. The main mechanism of these MAs is the sequestration of carbon from atmospheric CO_2, into organic matter, or the prevention of CO_2 emission through loss of carbon in organic matter.

The low value for wetland/peatland conservation/restoration relates to the small area of land that this MA is applicable to.

The first five of the six MAs in the bar charts have an estimated uptake of 1%, so the values in the two charts (a) and b)) are the same (although the scales are different). The sixth MA (management of existing woodland etc.) has a higher estimated uptake factor (10%), so the mitigation potential in the second bar chart is greater relative to the other MAs, then in the first bar chart.

Figure 69: Mitigation potential (kt CO_2e/y; median values) for mitigation actions related to land use: a) mitigation potential for the EU28 per percentage point of uptake; and b) mitigation potential for the EU28 calculated using estimates of likely uptake as presented in Chapter 4





In Figure 70 the mitigation potential values at EU level are shown, for crop production MAs. The main mechanism of these MAs is the sequestration of carbon from atmospheric CO_2, into organic matter, or the prevention of CO_2 emission through loss of carbon in organic matter. Reduced tillage mitigates emissions primarily by saving energy for soil cultivation. Zero tillage save more energy in this way, but also has much higher mitigation potential in semi-arid regions where the implementation of the MA may avoid the need for fallow, thereby increasing production over a rotation, with a net gain in soil organic matter. The other three MAs increase soil carbon sequestration, and use of cover/catch crops also interacts with use of N fertiliser and emission of N_2O from soil.

The use of cover/catch crops has increased relative magnitude of mitigation potential when estimated uptake is taken into account.

Figure 70: Mitigation potential (kt CO_2e/y; median values) for mitigation actions related to crop production: a) mitigation potential for the EU28 per percentage point of uptake; and b) mitigation potential for the EU28 calculated using estimates of likely uptake as presented in Chapter 4

Figure 71 gives mitigation potential values at EU level, for livestock production MAs. The values are low relative to most other MAs. This is a key result from this project, as it illustrates the low potential of these MAs to mitigate important and high emissions from livestock (especially methane from enteric fermentation in ruminant animals) and their manures.

The MA in this group with greatest mitigation potential is livestock disease management, which can allow greater efficiency and therefore greater output per unit of GHG emissions.

There are high emissions associated with livestock farming, but if we assume no change in consumption of products from livestock farming, then the potential to mitigate these emissions is low with actions that are currently developed.

Figure 71: Mitigation potential (kt CO_2e/y; median values) for mitigation actions related to livestock production: a) mitigation potential for the EU28 per percentage point of uptake; and b) mitigation potential for the EU28 calculated using estimates of likely uptake as presented in Chapter 4

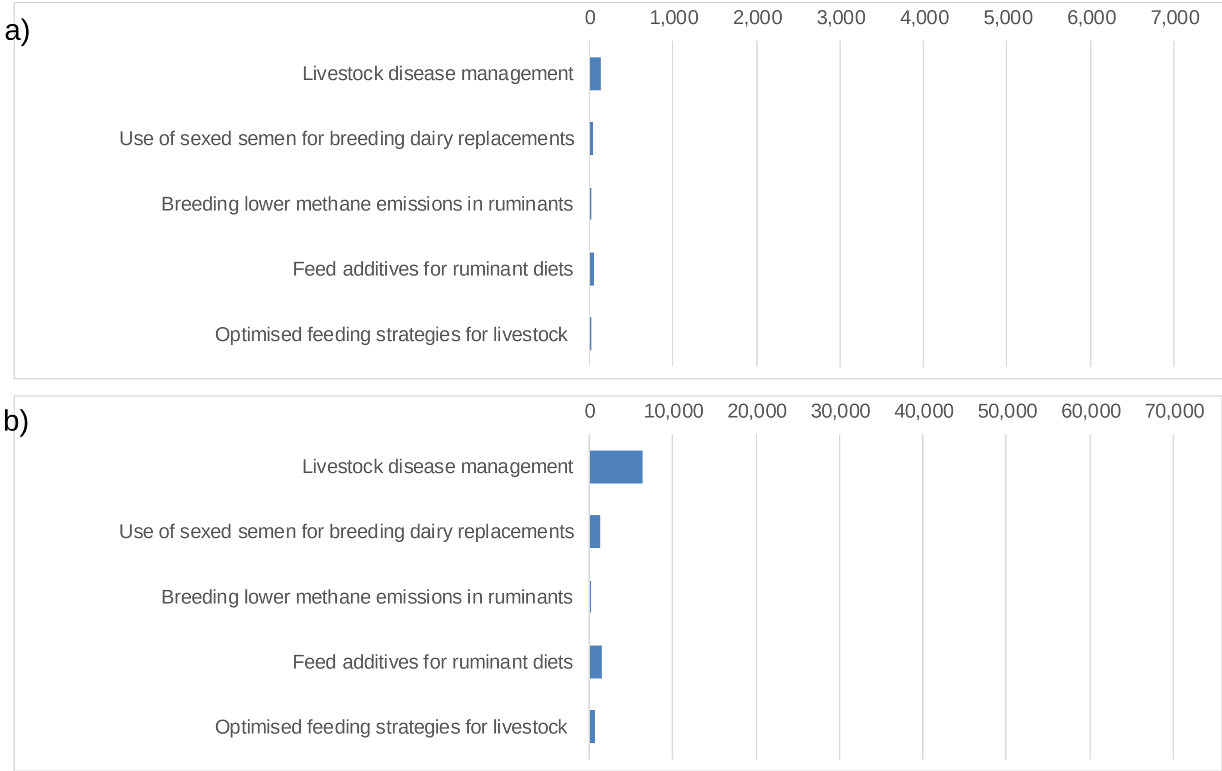


Figure 72 gives mitigation potential values at EU level, for mitigation actions related to nutrient and soil management. Use of nitrification inhibitors has significant potential to mitigate N_2O emissions from fertilizer application, and has the greatest mitigation potential of all the MAs that were considered in this project. Biological N fixation in rotations and in grass mixes has large potential to mitigate N_2O emissions from fertilizer application through decreased use of fertilizer, but leakage is likely as production of other crops will be displaced.

Figure 72: Mitigation potential (kt CO_2e/y; median values) for mitigation actions related to nutrient and soil management: a) mitigation potential for the EU28 per percentage point of uptake; and b) mitigation potential for the EU28 calculated using estimates of likely uptake as presented in Chapter 4

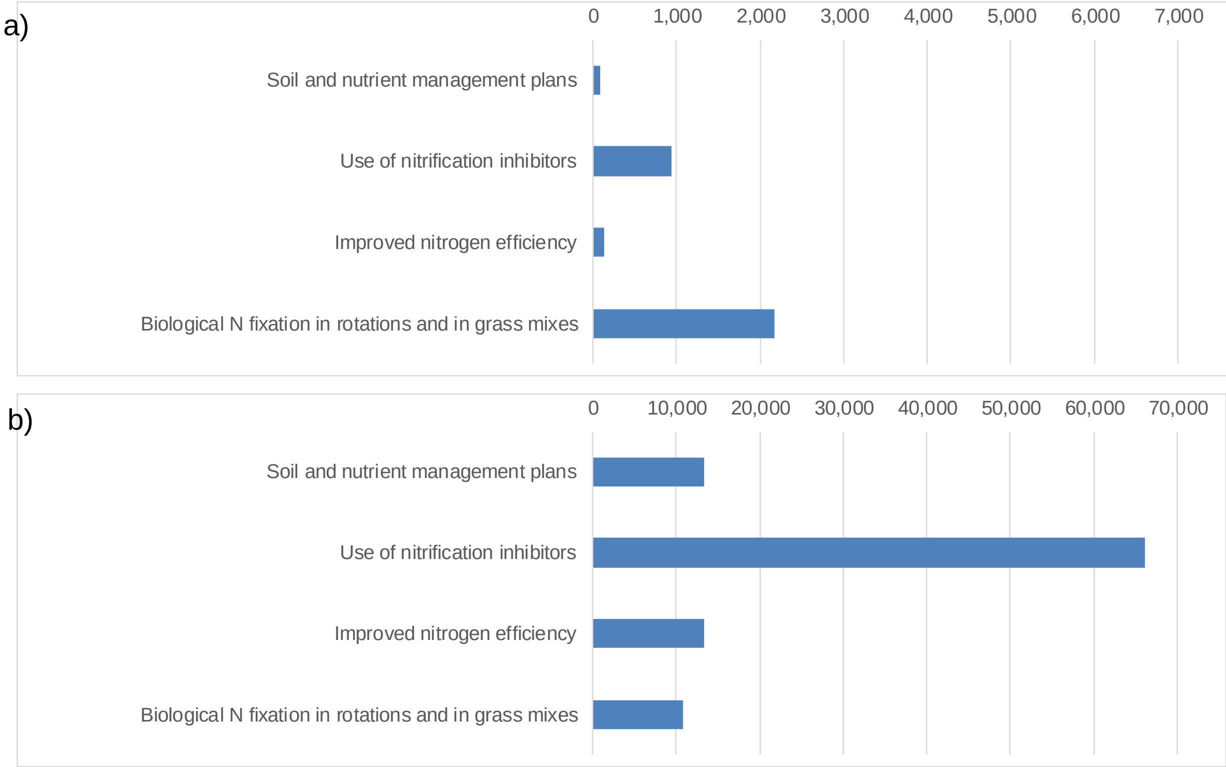
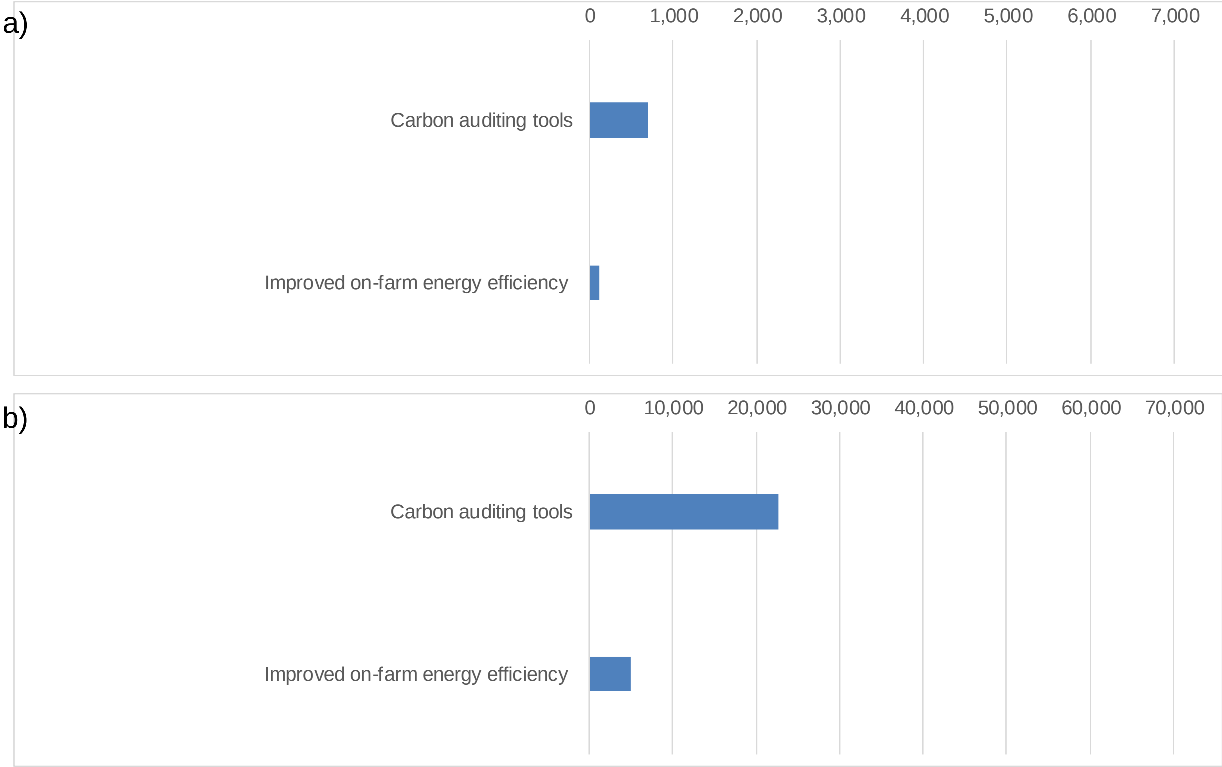


Figure 73 gives mitigation potential values at EU level, for mitigation actions related to energy efficiency. The GHG emissions from energy use in agriculture is low relative to emissions from other sources, so the mitigation potential is also low. The use of carbon auditing tools has greater mitigation potential than improved energy efficiency because it is a means of identifying and planning MAs across a wider range of emission sources. However, carbon auditing is often used to identify energy savings in the first instance, because of the associated cost savings.

Figure 73: Mitigation potential (kt CO_2e/y; median values) for mitigation actions related to energy: a) mitigation potential for the EU28 per percentage point of uptake; and b) mitigation potential for the EU28 calculated using estimates of likely uptake as presented in Chapter 4



Relative potential of mitigation actions

In Table 70 the mitigation actions are given in groups to show the conclusions with regard to mitigation potential per percentage point of uptake.

Of the 22 mitigation actions for which we assessed mitigation potential, 11 showed significant potential (more than 500 kt CO_2e/y at EU level). Of these, eight were related to land use, land use change or crop production, and were focussed on carbon sequestration; two related to mitigation of N_2O emissions from fertilizer application, and one (carbon audits) is a means of identifying relevant actions at a farm business level.

One mitigation action (zero tillage) had low overall potential, but is notable for high potential in a semi-arid regions where zero tillage can avoid the need for fallow and thus increase carbon sequestration.

The remaining ten mitigation actions had low potential. Of these, five were livestock production measures (reflecting the technical difficulty in mitigating emissions in this farming sector); two related to efficiency of nitrogen nutrition by crops and grass (reflecting the economic incentive not to over-apply nitrogen); two related to mitigation of GHG emissions through energy savings (reflecting the relatively low contribution of energy consumption to GHG emissions in agriculture and forestry); and one is a land use action (wetland/peatland conservation/restoration) that has limited potential because it is applicable to limited areas.

This relative categorisation of mitigation actions can be considered in more detail by reference to Section 3 (Analysis of mitigation actions), where the detail of each MA is provided. But, in making these high-level comparisons, we draw attention to two important points of context that need to be considered:

1. The comparisons are based mitigation potential values per percentage point of uptake, but the uptake percentage will be influenced by many factors;
2. Many of the MAs are associated with benefits and/or risks for other EU environmental objectives and in some cases with the potential displacement of production elsewhere.

Table 70: Mitigation actions in groups of greatest potential, large regional potential, and low potential

Mitigation potential group	Mitigation action
Greatest potential	Conversion of arable land to grassland to sequester carbon in the soil New agroforestry Woodland planting Preventing deforestation and removal of farmland trees Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land Leaving crop residues on the soil surface Ceasing to burn crop residues and vegetation Use cover/catch crops Use of nitrification inhibitors Biological N fixation in rotations and in grass mixes Carbon auditing tools
Large regional potential	Zero tillage
Low potential	Wetland/peatland conservation/restoration Reduced Tillage Livestock disease management Use of sexed semen for breeding dairy replacements Breeding lower methane emissions in ruminants Feed additives for ruminant diets Optimised feeding strategies for livestock Soil and nutrient management plans Improved nitrogen efficiency Improved on-farm energy efficiency

7.4 Analysis of National Inventory Reports and reporting categories

In Section 3, for each mitigation action, under the heading "Reporting of the mitigation effect", we provide a summary of the analysis of 28 National Inventory Reports. This analysis details key categories associated with each mitigation action relating to both the 1996 and 2006 IPCC guidelines. It also provides information on the number of MSs that recorded the relevant categories as key categories, whether the mitigation potential of a mitigation action is detectable within NIRs, and what IPCC tier method would be required to estimate the GHG impact of a mitigation action. A more complete analysis is provided to the Commission in a spreadsheet format, because it does lend itself to presentation in a text document, and it is easier to interrogate in a spreadsheet.

The ability to account for GHG emissions impacts of mitigation actions within inventories is dependent on:

- The availability of activity data or emission factors, and
- The methodology used.

Where there is a change in activity that can be identified through existing data capture mechanisms, the ability to account for implementation or scaling up of an action should be straightforward. Difficulties arise where the results of actions are more difficult to detect and need more detailed data gathering approaches, which can be costly. There are also mitigation actions listed in our analysis that have an indirect impact on emissions categories, which it will not be possible to account for.

For the actions that we have assessed through this project there are actions that:

1. Have a detectable impact on the emissions shown in the inventory and the impact can be specifically attributed to the implementation of the mitigation action;
2. Could have an impact on the emissions shown in the inventory but the effect cannot be specifically attributed to the implementation of the mitigation action;
3. May have no detectable impact on the emissions shown in the inventory but may improve carbon intensity of production.

For actions such as arable land conversion to grassland, or other land use actions where there is a change in practice over a defined area, there is a quantifiable way to record the activity data. In these case the challenge is likely to relate to calculation of emissions factors.

Challenges occur when attempting to quantify GHG impact of mitigation actions on inventories when:

- They are maintenance measures (i.e. maintenance of wetlands) as this requires a counterfactual basis for measurement of the impact;
- There is no means of measuring impacts according to inventory methodologies;
- Data collection is too onerous and costly;
- They have an indirect impact on emissions (e.g. livestock disease management, carbon audits).

The analysis is useful to help the understanding of whether implementation of each mitigations action will decrease the net emissions reported in NIRs, and whether any emissions decrease will be attributable to the implementation of the mitigation action.

The output of the analysis also allows the user to understand whether changes to methodology (e.g. change of IPCC tier method for the relevant category) would allow any net emissions decrease to be attributable to the implementation of the mitigation action.

However, it is not only the methodology tier, and/or the availability and accuracy of emission factors that influence the ability to account for mitigation, but also the availability and accuracy of activity data. For example, data on land use may be collected infrequently (perhaps at 5 or

10 year intervals), but there may be good methods and emission factors for estimating GHG emissions from some types of land use change. The methods may be Tier 3 methods and the category of emissions may be a key category, but there will be poor emissions estimates if the activity data is incorrect.

7.5 Implementation of climate mitigation actions

The use of CAP policy mechanisms to encourage uptake of climate mitigation actions

The implementation of most of the climate mitigation actions identified in this study as having the greatest mitigation potential in Member States can be supported in one way or another via the CAP, either by using financial incentives to pay farmers managing arable, livestock and mixed systems to carry out certain management practices (e.g. via many of the rural development measures as well as elements of the green direct payments), by attaching conditions to the receipt of payments (e.g. via cross-compliance) or through the provision of advice, information and training.

However, it has not been possible to elicit the extent to which these CAP policy mechanisms are either currently available to farmers in Member States or subsequently taken up by farmers, as the data on the utilisation of most Pillar 2 rural development measures were not available at the level of detail required for this type of assessment. As a result the impact to date of the CAP in meeting the mitigation potential of these actions has not been possible to determine.

Despite not being able to quantify the impact of CAP measures to date, the evidence shows that the agriculture sector remains a significant emitter of non-CO_2 emissions and that action is also needed to prevent CO_2 emissions or reduce these where they are occurring. It is also clear from experience to date that Member States have taken very different approaches to addressing climate mitigation in the agricultural sector. Decisions are driven by geographical differences in land use, management, soils and climate, making some actions more suitable or effective in one place than another, although it is apparent from some of the examples available, that the way in which the CAP measures are deployed in different Member States does not always match the climate mitigation actions with the areas where these would be of highest priority. However, other differences in approach may simply be due to a Member State focusing their climate mitigation policies on other sectors or choosing to encourage the uptake of mitigation actions in agriculture and forestry without using the CAP.

It is also clear that there are a few areas where the CAP legislation and related processes could be improved or the rules and Commission guidance to Member States on implementation strengthened to enhance the climate mitigation potential of certain measures. These include:

- **Increase the policy focus on the protection of carbon rich soils on arable and grassland** through altering the design of certain measures or the rules associated with them. In relation to green direct payments, this could include amending the permanent grassland greening measure to prevent ploughing on all carbon rich soils (e.g. through introducing farm level authorisations procedures or requiring the designation of carbon rich soils where no ploughing may take place). On arable soils, equivalence schemes could be introduced to tailor the EFA measure to minimise losses of soil organic carbon. Enhanced protection could also be provided via cross-compliance with the introduction of a new GAEC standard to prevent the ploughing of carbon rich permanent grasslands and require certain soil management activities on carbon rich arable soils. The use of rural development measures also should be enhanced not just to protect, but also restore carbon rich soils (e.g. peatland and wetlands).
- **Revisit the design and implementation of CAP measures to enhance their climate mitigation potential more generally**, particularly the new green direct payments – for example considering the potential of offering farmers combinations of

measures under the EFA measure which focus on climate mitigation or developing equivalence schemes with this purpose.

- **Greater promotion of CAP measures that support woodland planting/afforestation and the introduction of new agro-forestry systems**. Although measures exist under Pillar 2 that can be used for this purpose their use has been very low to date.
- **Improve the targeting of Pillar 2 measures** to ensure that climate mitigation actions are implemented in those areas where they are likely to have greatest mitigation potential.
- **Encourage greater EU level sharing of best practices** of how the CAP has been used to support climate mitigation actions in different regions of the EU, for example via the European Network for Rural Development's Contact Point.
- **Encourage the introduction of pilot projects** in Member States to demonstrate innovative ways to improve the efficient and effective use of CAP support for climate mitigation purposes.
- **Make use of the new Operational Groups as part of the European Innovation Partnership** to promote greater links between researchers and farmers and encourage innovation approaches to climate mitigation.
- Find ways to **ensure that the climate mitigation effects** of all CAP measures even where the primary objective of the intervention may not be climate mitigation **are recognised and reflected in Member States' monitoring, reporting and evaluation exercises**, as required under the CAP's Common Monitoring and Evaluation Framework (CMEF)
- **Enhance the coordination of reporting and monitoring for NIRs and CAP policy implementation** so that the requirements are considered together and tools and data shared for a more streamlined and cost-efficient process.
- Put criteria in place to **ensure the effect of policy decisions are positive for GHG emissions, based on the net effect of all policy measures 'at the farm gate**. This is required to avoid negating the impact of climate mitigation actions through other policy choices which may allow loss of carbon stores or sequestration potential, for example offering payments for conversion of arable land to grassland whilst permitting ploughing up of permanent grassland by individual farmers until the threshold has been reached at Member State level.

Barriers to the uptake of climate mitigation actions and solutions

There are a number of reasons why Member States may not be using the CAP measures available on a significant scale to achieve climate objectives. There may be policy or politically related reasons, such as: competing priorities or political inertia; whether or not mitigation actions are visible in UNFCCC GHG emissions reporting; synergies and conflicts with other environmental or agricultural objectives; risk averse behaviour in CAP implementation; the real and perceived complexity of CAP implementation for 2014 to 2020; as well as the under-representation of climate mitigation actions in formal CAP monitoring and reporting processes. There may also be a range of technical barriers with which to contend, such as gaps in knowledge, methodologies and data required for implementing and reporting climate mitigation actions.

Many of the CAP measures that can be used to support climate mitigation actions are voluntary for farmers to engage with (with the exception of cross-compliance and the green direct payments). Therefore it is also important to recognise the factors that influence the uptake of climate mitigation actions by individual land managers: for example the costs of implementation and other impacts on the farm business, technological and socio-cultural constraints, lack of awareness and knowledge of the reasons for taking action and its consequences as well as the shortfalls in the availability of and advice on the implementation of the action; and the absence of tangible individual benefits of the action and concerns about potential risks.

Barriers to adoption of climate mitigation actions by Member States

The political will to secure GHG reductions from agriculture will vary from one Member State to another for many reasons, including the overall priority given to climate policy, the relative importance of agricultural emissions within a Member State's total emissions and the extent of influence of the farming organisations. Despite the greater emphasis on climate action in in the CAP for the 2014 to 2020 period, Member States may choose to prioritise wider climate goals, or focus CAP measures on climate adaptation rather than mitigation or on different economic, environmental or territorial objectives. The absence of clear emission reduction targets specifically for the agricultural sector, either for non-CO_2 or CO_2 emissions in the EU means that the agricultural sector does not have clear strategy or goals to attain for GHG emissions (unless specific sector related strategies and targets have been developed nationally). The development of more detailed and specific national sector related strategies and targets would help engender greater understanding and investment in the farm and forest sectors. This needs to go hand in hand with raising the awareness of these climate priorities and goals to stakeholders and individuals in the land use sector and incorporating them into policies to provide the agricultural sector with clearer expectations regarding the direction of travel required.

In relation to climate reporting and policy tools, Member States are less likely to be interested in using CAP funding for mitigation actions where the GHG effect will not be identified in their GHG emissions inventory and reported in their NIRs. For example: nitrification inhibitors, biological N fixation in rotations and grass mixes, livestock disease management or tools where the mitigation benefit depends not on the measure itself, but the subsequent management changes made on the ground (e.g. carbon audit tools, soil and nutrient management plans).

In designing RDPs, it may be seen as more cost-effective to prioritise RDP measures to support mitigation actions where these can be designed in a way that also deliver other objectives (e.g. competitiveness, climate adaptation, reduced risk of soil erosion/diffuse pollution/flood, biodiversity). Many of those identified as having greatest mitigation potential in most Member States do have benefits for other environmental and economic objectives. Conversely there may be a reluctance to implement actions which only address climate mitigation. The development of guidance for Member States on how to design mitigation measures in a way that maximises benefits and eliminates risks for other environmental priorities – win-win policy design – would be beneficial. With multi-objective measures and schemes, an issue that has been identified, is whether or not it is possible to identify through the official reporting and monitoring processes those actions that are contributing to climate mitigation, and the risk that climate mitigation actions may go under-reported by Member States because their objectives extend beyond the climate sphere. To overcome this issue: ways need to be found within the CAP's Common Monitoring and Evaluation Framework (CMEF) to formally recognise and report on the many climate mitigation effects that are secondary benefits of measures used primarily to address other environmental objectives on farm and forest land, such as mitigating risks of soil erosion or diffuse pollution, creating or restoring wildlife habitats, growing biomass for renewable energy. This would help generate a clearer sense of the potential climate mitigation reach and subsequent impact of all CAP measures even where the primary objective of the intervention is not climate mitigation.

The implementation of some CAP climate mitigation measures, and the supporting data needed for targeting them to the appropriate farms / farmland (IACS/LPIS) depends on decisions/definitions made by Member States elsewhere in their process of CAP implementation, for example the definition they adopt of 'agricultural area' and within that 'permanent grassland[66]. If Member States choose to define permanent grassland in a way that excludes semi-natural pastures and other pastureland with trees and shrubs, this land will not be recorded on IACS/LPIS and Member States cannot designate these as 'environmentally sensitive permanent grassland' protected from ploughing. This could exclude important

[66] Article 4(1)h and (2) of 1307/2013

existing stores of soil carbon and carbon rich soils from protection/sequestration measures under the CAP.

Finally Member States face issues of data availability to enable the accurate reporting and evaluation of the climate mitigation effects of actions implemented on farmland. One frequently mentioned problem is that IACS and LPIS, which are critical CAP data sources, provide fine-grained land use data, annually updated, but the potential of this resource for climate reporting is vastly underused for a host of reasons, including access to the data due to privacy issues, coverage of the data and consistency with other data sources, Many Member States could make much better use of IACS/LPIS data to develop coherence with National Inventory reporting, but the current objectives, specification and set up of IACS provides no incentive for paying agencies to do this or even to share data; they are understandably risk averse and concerned about data protection rules, but these problems can be overcome, as some Member State have demonstrated. It is therefore a priority to find ways of making more effective use of LPIS/IACS, particularly by extending its capacity to reflect the rapid and continuous transformations that take place on agricultural land in consistent time series.

Costs and barriers to adoption of climate mitigation actions by land managers

For land managers, the cost/benefit balance to them is their primary consideration when deciding whether or not to implement a mitigation action and they tend to be cautious. Farmers are most likely to respond to actions which they can see will provide tangible business benefits (efficiency, reduced costs) and are backed up by evidence of practical and economic benefits. It is preferable if the evidence is from experience of implementation on other farms. Actions that bring no direct benefit to the farm business, or delayed benefits, or have risks of losing entitlement to CAP payments or future business flexibility through land use change, will be difficult to 'sell' to farmers even with financial incentives.

It is clear from the review of the literature that the costs of the different climate mitigation actions vary greatly depending on the types of activity involved, the extent to which they entail departures from current or likely future agricultural practice and the degree to which new investment is required or opportunity costs arise. Where changes are made within an existing crop or livestock system or between systems the balance between net savings and net costs will differ from one farm to another, and can only be identified at farm level. Opportunity and investment costs, as might be expected, are associated with significant changes in land use, although these changes may bring benefits from an alternative income stream in the longer term.

Amongst the actions with the greatest mitigation potential, those that are likely to entail the highest costs to farmers are: conversion of arable land to grassland, agroforestry or woodland, the use of nitrification inhibitors, and cover/catch crops, although of course this will vary according to individual circumstances. For some actions the net cost may be influenced by the availability of local markets, for example leaving crop residues on the soil surface may be a cost to the farmer who already sells straw as biomass or livestock bedding. Conversely, those actions with greatest potential that are likely to be cost neutral or even cost saving are biological N fixation in rotations and grass mixes, and ceasing to burn arable crop residues. This latter group should not require financial support to encourage their increased uptake, although where these actions are not widespread there may be a need for awareness raising and advice provision, with a focus on the potential economic benefits to the farm. For those actions where high costs to farmers are evident and the action is shown to have a high mitigation potential, the possibility of supporting this action via policy should be considered. For many of these actions (for example those requiring some form of land use change) the measures are already available under the CAP, but their use may need to be given higher priority than in currently the case. For others, such as N inhibitors, other policy solutions may need to be found (*see below).*

Besides the business case for the implementation of actions, the presentation of mitigation actions to farmers is also important. Farmers will more readily see the point of doing something to improve their own land and business performance rather just for the altruistic benefit of climate mitigation for society as a whole. There is also a need to be aware of the risk to climate mitigation actions from farmers' perceptions of their best course of action to optimise their income. For example, depending on how the rules have been applied in the Member State, farmers may interpret the rules on eligibility of farmland with trees for BPS and other CAP support as an incentive to fell or prune existing trees, to maximise their eligible area for CAP payments. In other cases the technological developments are ahead of policy developments, for example farmers growing some crops on rewetted peat (paludiculture) e.g. Sphagnum, are ineligible for direct payments if the new crops are not recognised as 'agricultural'.

7.6 Key messages

1. A list of mitigation actions has been reviewed; information is provided to aid understanding of their potential.
2. Project outputs enable a user to:
    - find estimates of mitigation potential per percentage point of uptake, and for an assumed level of uptake;
    - scale mitigation potential using decision trees that are provided;
    - understand the geographic applicability of each action;
    - find qualitative information on (e.g.) mode of action, barriers etc. to support the values provided;
    - understand the contribution of the mitigation to reported emissions values by category in NIRs.
3. Mitigation actions with high potential include those that:
    - decrease emission of N_2O from soil nitrification inhibitors; biological N fixation;
    - encourage good management of all inputs and outputs; carbon audits;
    - increase carbon stock on the land arable to grassland conversion; woodland management.
4. Mitigation actions associated with livestock systems performance generally have low potential; for example, sexed semen for breeding; optimised feeding.
5. Indirect mitigation and leakage are important, but do not influence abatement targets or NIRs. For example, growing more N-fixing crops can lead to displacement of other crops and emissions from indirect land use change; some emissions from N fertilizer production often occur outside the country where mitigation actions can decrease use of fertilizers
6. Some mitigation actions cannot currently be supported for policy development, based on existing evidence. These are:
    - Improving grassland management to sequester carbon
    - Use of grassland to reduce fire risk
    - Biochar applied to soil
    - Extend the perennial phase of crop rotations
    - Delay applying mineral N to a crop that has already had slurry applied
    - Maintain soil pH at suitable levels for crop/grass production
    - Increased on-farm biogas production
7. The CAP contains many measures which can be used to contribute to climate mitigation activities in relation to agriculture and forestry, both through conditions placed on farmers via cross-compliance, the greening payments under Pillar 1 as well as voluntary measures

under rural development policy. The majority of mitigation actions identified in this study, particularly those related to the management of agricultural soils (e.g. reduced fertilizer inputs, crop rotations, reduced tillage etc), land use management and changes (e.g. converting arable to grassland, peatland restoration, afforestation and agro-forestry) can already be supported under the measures available within the CAP. The CAP, therefore has an important role to play, at least in the short-term, in encouraging and supporting the agricultural and forest sectors to reduce greenhouse gas emissions and increase removals.

8. Many of these policy measures are used already in a range of Member States. However, their uptake is patchy and not necessarily targeted at the areas where the greatest climate mitigation benefits could be achieved. Member States have considerable freedom of choice in the way in which they implement the CAP (including many Pillar 1 measures) and are faced with a range of policy priorities and political pressures.

9. The degree to which policy intervention is necessary is influenced by the climate benefit likely to be realised in practice, combined with the net economic effect of implementing the mitigation action on farm businesses. For example, actions which are economically beneficial to the farm will not require payments to incentivise their introduction, whereas those that are cost neutral or have a net cost may require some support. Climate mitigation actions that bring no direct benefit to the farm business, or have climate benefits that are accrue over a longer timeframe or involve significant opportunity costs or investment are most likely to require financial incentives. All actions are likely to benefit from support measures, such as knowledge transfer, advice and training to ensure that the mitigation actions are implemented optimally on the farm.

10. Climate mitigation actions that are also beneficial for other environmental objectives (e.g. combatting soil erosion, improving water quality, maintaining or enhancing biodiversity) are likely to be more attractive to policy makers in Member States. Other considerations that will also influence the choice of measures is the extent to which the climate mitigation actions can be accounted for within National Inventory Reports. The potential impact on production, if this is likely to be displaced elsewhere, will also be a relevant consideration for some climate mitigation actions.

11. The administrative costs of implementing these actions via the CAP are relatively low unless new data is required for targeting and monitoring/controls. This is because the most significant costs associated with the running of the CAP are already in place in all countries.

12. When designing policy measures to incentivise climate mitigation actions, it is important to consider the net effect of all policy measures ‘at the farm gate’. It is counterproductive if policy incentives to encourage changes in farm management practices to reduce GHG emissions are negated because other policies allow losses of carbon stores or sequestration potential, for example from the way in which farmers manage existing grasslands, carbon-rich soils and wetlands.

13. The degree of ability to account in national inventories for abatement from some mitigation actions is a barrier to investment and implementation.

8 Annexes

Annex 1	Candidate action screening
Annex 2	Assessment and ranking of candidate actions
Annex 3	Member State mitigation potential information tables
Annex 4	Additional information on administrative effort
Annex 5	Use of CAP policy tools to improve uptake of climate mitigation actions
Annex 6	March 2015 Workshop Report
Annex 7	September 2015 Workshop Report
Annex 8	Review of LULUCF consultation responses

RICARDO-AEA

The Gemini Building
Fermi Avenue
Harwell
Didcot
Oxfordshire
OX11 0QR

Tel: 01235 75 3000
Web: www.ricardo-aea.com