Annexes to:
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/Final Report Annex
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

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08 January 2016

Ricardo-AEA reference:

Ref: ED60006/Final Report Annex- Issue Number V1.1

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Annex 1: Candidate action screening

This document provides information for each of the 28 mitigation actions. The tables used to present the information for each mitigation action use the format proposed in Table 2 on page 13 of the bid.

Table of abbreviations

Abbreviation	Term
AD	Anaerobic digestion
BG	Biogas
C	Carbon
$CaCO_3$	Calcium carbonate
CAP	Common agricultural policy
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalents
CS	Cattle slurry
CT	Conventional tillage
DCD	Dicyandiamide
DM	Dry matter
DMPP	3,4- dimethylpyrazole phosphate
EC	Elemental carbon
GHG	Greenhouse gas
GNB	Gross Nutrient Budget
Gt	Gigatonne
GWP	Global warming potential
IPCC	International Panel on Climate Change
KNO_3	Potassium nitrate
LW	Live weight
MA	Mitigation action
MACC	Marginal abatement cost curves
MCF	Methane Conversion factor
MS	Member states
N	Nitrogen
N_2O	Nitrous oxide

NH_3	Ammonia
NH_4^+	Ammonium
NIs	Nitrification inhibitors
NO_3^-	Nitrate
NRE	Non-renewable energy
NUE	Nitrogen use efficiency
NVZ	Nitrate Vulnerable Zone
OC	Organic carbon
OSR	Oilseed rape
P	Phosphorous
PAHs	Polycyclic aromatic hydrocarbons
PM	Particulate matter
RMP	Recommended management practices
RT	Reduced tillage
SEAAs	Synthetic essential amino acids
SFM	Sustainable forest management
SO_2	Sulphur dioxide
SOC	Soil organic carbon
ZT	Zero tillage

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

Introduction

This mitigation action is considered with respect to its potential for sequestering C in the soil.

The CLIMSOIL project (Schils *et al.,* 2008) concluded that grassland soils generally accumulate C, although with a large uncertainty. Soussana *et al.,* (2010) report a meta-analysis of 115 studies on pastures and other grazing lands worldwide (Conant *et al.,* 2001), which indicated that soil C levels increased with improved management (primarily fertilization, grazing management, and conversion from cultivation or native vegetation, improved grass species) in 74% of the studies considered. For this candidate mitigation action we only consider conversion from tillage land and exclude conversion from native species.

Table recording results of the evaluation of conversion of arable land to grassland to sequester carbon in the soil

Mitigation potential	The amount of C that can be sequestered will 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 tillage, with a small SOC content will be able to sequester more C. The capacity to sequester C increases with increasing clay content. Recent work from Scotland reports 31.1 (+/-0.3) g C m^{-2} y^{-1}. (Rees, pers comm). Subsequent grassland management, e.g. fertilizer inputs and intensity of grazing will also influence the C sequestration potential. *Arable land converted to grassland will need to be maintained as grassland as reversion to tillage land will release the C sequestered under grass.*
How effective is the action across the EU?	This will vary somewhat depending on current SOC status which will be least on long-term arable soils. However, the action is likely to increase SOC when any arable soil is converted to grassland.
How sensitive is the action to farmer implementation?	Not very sensitive since conversion of arable land to grassland is a clearly defined action.
Compatibility with farming systems	The main constraint will be finding a use for the grass. The most likely use is for cattle and sheep but grass may also be used as a feedstock for biogas (BG) production. The sequestration potential will be greatest for soils that have been in arable rotations. However, if the farm does not already have livestock, or a BG plant, this will require a major change in farm practice and significant investment.
Impact on farm income	Could have a serious adverse impact on farm income if there is not a good market for the grass grown.
Verifiable	See below.
Field sampling and testing	Difficult; soils need to be sampled to at least 1 m, and a rigorous protocol, including taking bulk density samples, needs to be followed.

	Verification by direct soil sampling is likely to be too expensive and subject to large uncertainties.
Remote sensing	Can be used to record change in land use.
Record Inspection	Can be used to record change in land use.
Other	Modelling soil C will be a less expensive option but also subject to uncertainties
Co-benefits	Conversion from tillage land to grassland will reduce soil erosion and is also likely to lead to reductions in nitrate (NO_3^-) leaching and phosphorus loss to watercourses. There should also be potential for increased biodiversity. However, some of these potential co-benefits may be reduced, or even lost, if the grass is intensively managed. Heavy deposits of excreta by grazing livestock can increase NO_3^- and P losses, in particular by run-off in areas of high rainfall, while intensively managed grassland may be no more biodiverse than arable land. In addition, conversion of arable to grassland is unlikely to be cost-effective unless it enables the establishment or expansion of a profitable livestock enterprise or the grass produced can be used by another farm.
Any adverse environmental impacts	Arable production may be reduced, potentially leading to increased production in other regions where GHG emissions per tonne of product may be greater than in the EU. Increasing the area of grassland in areas of livestock production may lead to greater use of grass in ruminant diets countering trends to replace grass forage with maize-based forage and thereby increasing emissions of enteric CH_4.
Social acceptance	This is likely to be good, at least initially. However, if conversion to grassland is accompanied by intensive livestock production, problems may be caused by odour nuisance. Other factors arising from change in land use may also influence social acceptance.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) did not consider conversion to grassland, although the introduction of 1 to 3 years of a perennial crop was one option reviewed. 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 SOC storage. They can also generate more total evapotranspiration, dry soils, and reduce soil C decomposition rates.

Conversion to grassland was found to have the greatest technical potential for C sequestration of the six measures evaluated by Lugato *et al.,* (2014), with median annual rates of sequestration of *c*. 0.6 t/ha C up to 2020.

Key points

Factors influencing amount of carbon sequestration

- In mineral soils, fertilization of grassland is generally considered to enhance C storage due to enhanced productivity (O'Mara, 2012). A positive correlation between C sequestration and N fertilization has been observed in managed grasslands (Jones *et al.,* 2006).
- Sousanna *et al.,* (2004) stated that N fertilization may increase net ecosystem production in moderately fertile systems, as the increase in production outweighs any

concurrent increase in decomposition. In more organic-rich mountain pastures, due to the relatively large pool of organic matter available for decomposition, N fertilization may trigger large carbon losses. Morris *et al.,* (2010) reported that 'semi intensive' grassland farming, with moderate levels of mineral and organic fertilizer, could offer a commercially feasible peatland 'conservation and carbon storage' option, especially in dairy areas, with modest returns of €65 to €270/ha. This would require high standards of management in order to meet environmental objectives. The 'opportunity cost' of taking land out of agricultural production is likely to reduce over time as peatlands are degraded and become less agriculturally productive.

- 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).
- Irrigating grasslands can promote soil carbon gains (O'Mara. 2012).
- Enhancing species diversity and, in particular, introducing new deep-rooted grasses with greater productivity into the species mix has been shown to increase soil carbon, particularly on low-productivity pastures (Tilman *et al.,* 2006).

Influence of grazing by livestock on carbon sequestration by livestock

The intensity and timing of grazing (and livestock species) can influence the removal, growth, carbon allocation, and flora of grasslands, thereby affecting the amount of C accrual in soils. Follett and Schuman (2005) reviewed grazing land contributions to C sequestration worldwide using 19 regions. A positive relationship was found, on average, between the C sequestration rate and the animal stocking density, which is an indicator of the pasture primary productivity. However, the effects of grazing intensity are inconsistent. Both under- and over- grazing can reduce carbon sequestration or lead to carbon loss from soils (Rice and Owensby, 2001; Liebig *et al.,* 2005): The CLIMSOIL report (Schils *et al.,* 2008) attributed this variation to the many types of grazing practices employed and the diversity of plant species, soils, and climates involved.

Soussana *et al.,* (2007) found that across sites, net C sequestration declined with the degree of herbage utilisation by herbivores through grazing and cutting, which underlines that grassland C sequestration per unit area is favoured by *extensive management provided that nutrients are not limiting* (Allard *et al.,* 2007; Klumpp *et al.,* 2007).

Applicability

The method is applicable to all forms of tillage land, but whole-scale conversion is potentially most suited to marginal tillage land that was historically kept as grazing land (e.g. steeply sloping land, shallow soils) (Bhogal *et al.,* 2009). Large scale conversion of tillage land to permanent grassland is an extreme change in land use, requiring a change in farm business outlook. It is unlikely to be adopted without the provision of suitable financial incentives, due to the drastic impact on farm practice. It may be particularly suited to areas where the converted land would have amenity or conservation value.

Timescale over which mitigation action becomes effective and duration

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 restorative land use or RMP are followed, and sequestration rates can continue for 30 and up to 50 years.

Leakage (production displacement)

As a result of converting arable land to grassland, leakage may occur via two mechanisms.

First, arable production may be reduced potentially leading to increased production in other regions where GHG emissions per t of product may be greater than in the EU.

Second, increasing the area of grassland in areas of livestock production may lead to greater use of grass in ruminant diets countering trends to replace grass forage with maize-based forage and thereby increasing emissions of enteric CH_4. Additionally, whereas the capacity of soil to sequester C is limited, and will reach an equilibrium even under grassland, any resultant increases in enteric CH_4 emissions arising from increased livestock numbers are likely to continue, unless other mitigation actions are introduced to mitigate them.

Conclusions

- Conversion to grassland will sequester carbon in soil for as long as the land remains as grassland.
- However, an equilibrium will be reached after which there will be no further increase in C storage.
- The exact amounts of C sequestered are very difficult to predict as the process depends on soil type, climate and grassland management. Cultivating to re-seed pastures will release some of the C sequestered.
- This mitigation action should be considered further as it offers a well proven approach to sequestering carbon in soils. However, given the potential for leakage this mitigation action does not appear to be among the most suitable mitigation actions for further promotion.

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New agroforestry

Introduction

This mitigation action is considered with respect to its potential for sequestering C in the soil.

Agroforestry is the practice of integrating trees and shrubs with the production of food crops or livestock. This holds 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).

Table recording results of the evaluation of new agroforestry

Assessment criteria	**Evaluation results**
Mitigation potential	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). 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). However, 'the type of agroforestry systems and their capacity to sequester C vary globally' (Oelbermann *et al.,* 2004). According to Povellato *et al.,* (2007), whilst the agroforestry sector acts as a sink for CO_2, it may also be a source of N_2O and CH_4 emissions.
How effective is the action across the EU?	Widely applicable where soil type and topography allow cultivation of soil for crop production.
How sensitive is the action to farmer implementation?	Farmers need to be quite motivated to adopt this practice (Aertsens *et al.,* 2013) as the introduction of agroforestry requires significant changes to crop husbandry and farm management. 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 action is highly sensitive to farmer implementation.
Compatibility with farming systems	Farming systems will change when agroforestry is implemented, so the action is not compatible with maintenance of non-agroforestry systems. 'Europe has a potential of 90 million ha for productive growth of trees on arable land (Dupraz *et al.,* 2005) and on 65 million ha of arable land this would lead to additional environmental benefits (e.g. less erosion, NO_3^- leaching, increase landscape diversity) (Reisner *et al.,* 2007)' (Aertsens *et al.,* 2013). It is expected that some 50 million ha of pastureland would be available in Europe for the introduction of agroforestry (Aertsens *et al.,* 2013).

	However, when agroforestry is carried out, cultural practices carried out for annual crops may need to be altered (Calfapietra *et al.,* 2010). Thus farmers may not choose to implement this mitigation action.
Impact on farm income	Labour and material costs will be increased (at least in the first year where profits may also be lower). However, a study cited within Kursten (2000) found that four year profits were much greater for an agroforestry system than either crops or forestry in isolation.
Verifiable	'Processes in agroforestry systems are complex and many interactions are difficult to measure or model' (Luedeling *et al.,* 2014).
Field sampling and testing	Verifiable by field visits to identify change to agroforestry.
Remote sensing	Images could be used to determine the extent of land area converted to agroforestry.
Record Inspection	
Other	
Co-benefits	• Reduction in soil erosion • Reduction in NO_3^- leaching • Pest control • Increased biodiversity • Soil fertilization • Creation of a cooler microclimate • Wind speed reductions • Enhanced soil moisture • Increased water use efficiency • Aesthetic value • More resilient to climate change than monocultures • Biomass production • Reduction in dependency on timber products from abroad • Watershed management • Reduction in flood risk • More diverse soil microbial communities George *et al.,* (2012) also argues that agroforestry will alleviate dryland salinity as well as stabilising agricultural systems. Agroforestry may result in a decrease in deforestation: Dixon (1995; cited in Oelbermann *et al.,* 2004) 'estimated that for each hectare of sustainable agroforestry production, up to 5 ha of deforestation could be prevented'. Rivest *et al.,* (2013) suggest that agroforestry will bring increased microbial substrate use efficiency and microbial resilience which would increase crop productivity and improve tolerance to severe water stress, particularly in heavier soils with older trees.
Any adverse environmental impacts	At the local level – the agricultural field where the trees are planted – there may be a decrease in food production. However, globally, food production would not be affected in theory because agroforestry is estimated to be more efficient than food production and forestry systems separately (Aertsens *et al.,* 2013). The maintenance of food production

	would require balancing changes in production systems, between forest to agroforestry and agriculture to agroforestry. If yields decrease locally, even on a short term basis, additional land elsewhere may be required to grow crops, leading to emissions associated with crop displacement (leakage).
Social acceptance	Environmental benefits are likely to lead to good social acceptability. This will be influenced by changes in economic performance, which may be decreased in early years, so social acceptance may be improved by financial support for conversion. Some countries in the EU support the introduction of agroforestry in their rural development programmes, however the support provided to date is not representative of the societal value presented by agroforestry (Aertsens *et al.,* 2013). 'If this value would be fully recognized by internalizing the positive externality, we expect that agroforestry will be introduced to a very large extent in the next decades, in Europe and the rest of the world, and this will importantly change the rural landscapes' (Aertsens *et al.,* 2013).

Ecologic evaluation

The Ecologic report (Frelih-Larsen *et al.,* 2014) mentions agroforestry as part of the measure 'establishment and management of shelterbelts and hedges to provide multiple adaptation benefit – adaptation' but little detail is included.

Key points

'Taking account only of the value for climate change mitigation, the introduction of agroforestry is estimated to have a value of 282 euro/ha in 2012 that will gradually increase to 1007 euro/ha in 2030' (Aertsens *et al.,* 2013).

Overall, effectiveness will be influenced by the scale of uptake and the extent and direction of indirect effects. Change from crop production to agroforestry will decrease crop production at the field scale, because the solar radiation will be shared with the trees. The effect on crop production across the EU and globally will depend on the extent of other changes, such as change from forest to agroforestry. The overall balance of change in crop production will determine whether there are additional emissions, and if so, the magnitude of these emissions, from indirect land use change. The change from forest to agroforestry may also lead to large emissions through loss of carbon stocks, at the time of conversion.

Conclusions

The value of agroforestry, based on the potential for carbon sequestration, is high on a field scale. However, there is uncertainty about effects at a landscape scale, and about emissions from crop displacement. With potential for many benefits to environmental services, as listed above, and the possibility that both crops/livestock and trees would increase productivity from agroforestry, we recommend this as a measure to take forward. However, the practicalities of introducing this measure may be a deterrent for farmers, and thus an incentive may be required.

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Wetland/ peatland conservation/ restoration

Introduction

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

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 for *c*. 10,000 years (Frolking *et al.,* 2006; cited in Bonn *et al.,* 2014). Although they cover only 3% of the global land area, peat soils accumulate 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).

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 increases significantly with land use change, the conversion of peat swamp forests to other land uses will have an impact on losses of soil C 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).

Table recording results of the evaluation of avoiding drainage of wetland/ peatland conservation/ restoration

Assessment criteria	**Evaluation results**
Mitigation potential	<u>Wetland</u> Limited evidence of the mitigation potential of non-peat wetland was found in the literature review. GHG abatement and costs depend on the degree of drainage that occurred within the wetland, the current land use intensity and the realised land rents. Overall net mitigation effect is positive. 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} $year^{-1}$ <u>Peatland</u> 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). Restoration of peatland by rewetting has been found to decrease CO_2 emissions. 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_2 eq ha^{-1} yr^{-1} will occur when peatlands are restored to near natural conditions (Bain *et al*., 2011; cited in Bonn *et al*., 2014). However, restoration of peatlands can increase N_2O and CH_4 emissions.
How effective is the action across the EU?	Degraded peatlands are responsible globally for 25% of CO_2 emissions from the land use sector, and in the European Union for 75% of GHG emissions from agricultural land use (Joosten, 2009; cited in Bonn *et al.,* 2014). Preventing further degradation of wetlands / peatlands and restoration of these habitats will reduce net emissions of CO_2. The restoration of wetland is not addressed by national legislation in all MS, and funding has been largely through nature protection funds, because climate objectives have not been the primary focus of restoration objectives. At the EU level, the Biodiversity Action Plan for the Conservation of Natural Resources and the Water Framework Directive include the objective to protect and restore wetlands (Frelih-Larsen *et al*., 2014).
How sensitive is the action to farmer implementation?	There is little sensitivity to farmer implementation as the action, to conserve wetland / peatland through avoiding drainage, is not greatly subject to interpretation. However rewetting for restoration may be sensitive because the fluxes of CO_2, CH_4 and N_2O are very sensitive to management of the water table.
Compatibility with farming systems	<u>Restoration</u> Wetland /Peatland restoration is compatible with agricultural soils classified as organic. To implement restoration would require a farming system management change, the scale of which depends on the size of the area for restoration. Arable / horticultural reversion to grassland requires significant management and infrastructure change to accommodate livestock. Reduction in intensity / or type of livestock may be more compatible. Opportunity to introduce paludiculture would also require management change. <u>Conservation</u> Protection of existing wetland/peatland will be compatible with the current farm system but may require adjustments to create buffer zones around the habitat to manage water levels and prevent nutrient enrichment.
Impact on farm income	Mitigation will reduce the gross margin per hectare. The degree of impact will depend on whether the mitigation is implemented on upland or

	lowland farms. There is the potential for offsetting through environmental subsidies in some EU countries. Restoration of wetlands will require land use change which is likely to decrease productivity of the land involved.
Verifiable	
Field sampling and testing	GHG monitoring is difficult and can only be achieved in controlled sites via techniques such as closed chamber techniques, which are impractical at a field scale. Site inspection should be able to determine if the field has been drained.
Remote sensing	
Record Inspection	Percentage change in wetland and peatland areas over time. Assisted by farm scale record inspection. Stocking rates could be used to measure the intensity of grazing on both wetland and peatland.
Other	To monitor the water level in wetlands/peatlands automatic loggers could be used.
Co-benefits	Carbon trading; 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). Help to meet biodiversity action plan targets for blanket and raised bog restoration. Biodiversity gains, decreased risk of habitat /wildlife loss. Improvements to water quality due to decreasing land productivity by reversion from arable or intensive grassland. Improved landscape value either through aesthetics or public accessibility. Mitigation for downstream flooding and fire risk by increasing water retention potential of restored peat. Also act as floodplains. Paludiculture could add value to wetlands Energy conservation due to farm system change. Reduction of carbon release from the action of burning drained peat.
Any adverse environmental impacts	Saturated soils can increase CH_4 emissions so potential pollution transfer from CO_2 to CH_4. Although net capture is likely to outweigh the net loss of GHG. Paludiculture could create conflicts with biodiversity.
Social acceptance	Opportunity for other businesses to offset carbon emissions through funding peatland restoration. Reduced productivity can have a socio-economic impact as well as a farm scale impact. E.g. reduced number of people living in the area due reduced job opportunities and therefore a change in community service provision such as schools. The MA may also be unpopular if it leads to an increase in biting insects such as mosquitos or midges.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) reviewed the restoration of wetlands to reduce GHG emissions. Three measures were discussed:

- 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). Achieved by decreasing production.
- No new drainages, renewal or deepening of drainages on organic soils.

The Ecologic report concluded that the expected impacts on GHG emissions would be:

- Reduced emissions of CO_2 as result of decreased decomposition of organic material.
- Reduced N_2O emission as a result of reduced soil mineralization.
- Increased CH_4 emission after rewetting should be avoided where possible by keeping the water table right below the surface, i.e. no flooding.

Frelih-Larsen *et al.,* (2014) (Page 71, Table 1) summarised the abatement rates found in a literature review and also the associated costs of operations for the measures discussed above.

Key points

Wetlands

Wetlands only become climate neutral when the water tables are very close to natural conditions (mean annual water table is around 10 cm below the ground surface level, no flooding to avoid CH_4 emissions) (Osterburg *et al.,* 2013; cited in Frelih-Larsen *et al.,* 2014).

Restoration of wetlands will be more cost effective than wetland extensification, because the GHG savings are typically greater.

Losses of C from peatlands will increase with peat drainage and land use change. These losses are magnified with arable conversion due to the soil disturbance.

Methane emissions more or less cease completely after drainage due to the change from anaerobic conditions in the soil.

Nitrous oxide emerges at rates that exceed those from mineral agricultural soils by a factor of 2 to 10 (Freibauer *et al*., 2004). In total, average GHG emissions from agricultural peat soils are estimated to range between 3.5 (2.2-5.2) t ha^{-1} $year^{-1}$ C-equivalents in grasslands, 4.9 (3.3 to 6.5) in croplands, and 6.5 (3.8 to 9.5) under potatoes or sugar beet (Freibauer, 2003; cited in Freibauer *et al*., 2004).

Morris *et al*., (2010) reported that 'semi intensive' grassland farming, with moderate levels of mineral and organic fertilizer, could offer a commercially feasible peatland 'conservation and carbon storage' option, especially in dairy areas, with modest returns of £50 to £200/ha. This would require high standards of management in order to meet environmental objectives. The 'opportunity cost' of taking land out of agricultural production is likely to reduce over time as peatlands are degraded and become less agriculturally productive.

Change as a result of climatic changes will also affect peatland GHG emissions (Farmer *et al*., 2011). Results show that climate change is expected to have an important impact and reduce the surface area of wetlands by 5.3 to 13.6%. In comparison, the impact of groundwater abstraction (100% increase in the expected scenarios) would lead to a maximum decrease of 3.7% (Landes *et al*., 2014). By decreasing or stopping land drainage the impacts of climate change and groundwater abstraction could be partially mitigated.

Impact on direct GHG emissions and removals

Wetlands

The expansion of constructed wetland and riparian areas for nutrient, pesticide, and faecal pathogen interception may elevate CH_4 and N_2O emissions, although such increases would also be relatively minor in the context of the UK-wide GHG budget (Rounsevell *et al.,* 2009).

A New Zealand study found that wetlands can emit about 140 kg CH_4 ha^{-1} $year^{-1}$, a figure that can vary greatly with the type of wetland, with wetlands purely reliant on rainfall emitting less CH_4 than wetlands kept hydrated by river systems (Saarnio *et al*., 2009; cited in Kirschbaum *et al*., 2012). However as wetlands also act as carbon sinks this tends to counter balance any CH_4 emissions.

Peatlands

The draining of peatlands typically results in an increase in net CO_2 emission and a decrease in CH_4 efflux, except in drainage ditches where increased CH_4 flux has been reported (Mahmood and Strack, 2011; Waddington and Day, 2007; cited in Strack *et al*., 2014).

Effectiveness (compared with current emissions) at a landscape scale

Although the Kyoto Protocol created an international market for carbon under the UN Framework Convention on Climate Change it would require legislative changes at EU and country level for these markets to be used to support peatland restoration in Europe (Bonn *et al.,* 2014).

In line with national and international obligations on biodiversity and climate, such as the 2020 EU Biodiversity Strategy (European Commission, 2011), the IUCNUK Commission of Inquiry on Peatlands suggested as an actionable target of 1 Mha of peatlands in good condition or under restoration management by 2020 (Bain *et al.,* 2001; cited in Bonn *et al.,* 2014).

The literature review suggested that incentive programs are viewed as being more flexible than regulatory regimes as they allow farmers to weigh the costs and the benefits before they choose to participate in the programme. However, incentive payments that conserve a significant area of wetlands will be very expensive to taxpayers and therefore politically unpopular (Claassen *et al.,* 2001; cited in Neuman *et al.,* 2011).

Indirect effects on GHG emissions (including leakage)

Negative effects include transfer of agricultural production to other sites and therefore the associated leakage.

Rewetting can increase emissions of CH_4 and N_2O until near natural state is restored. However GHG emissions are largely less than from drained wetlands.

Conclusions

It is recommended that the restoration of peatland wetland be considered for inclusion in the CAP as a mitigation option, also and in particular in view of the long list of co-benefits with regard to other ecosystem-services delivered by restored wetlands.

The inclusion of other wetland types would require more detailed review of the effectiveness for GHG mitigation.

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Woodland planting

Introduction

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 is not a given, and is much debated, specifically in the context of rewards that may be available for such measures and 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).

Table recording results of the evaluation of using woodland planting

Assessment criteria	**Evaluation results**
Mitigation potential	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). 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).
How effective is the action across the EU?	Forests and forestry contribute to climate change mitigation by preserving and expanding carbon stocks in the forests (including above- and below-ground biomass, deadwood, litter, and soil), by producing renewable materials in order to substitute fossil fuel and materials for which production costs much fossil energy, and by storing carbon in harvested wood products. Currently, Europe's forest cover is increasing by approximately 500,000 ha per year (SFC, 2010).
How sensitive is the action to farmer implementation?	Sathaye *et al.,* (2007) estimate that a maximum of 40 to 50 Mha of land in Europe will be available for afforestation based on the available land base. At an afforestation rate of around 750 thousand ha / yr, this maximum would be reached in 60 years. Eggers *et al.,* (2008) used modelling techniques to project the development of forest resources in fifteen European countries (closely mapped to the EU-15 but including Switzerland). In their three scenarios, Eggers *et al.,* (2008) arrived at an afforestation rate until 2030 that was only slightly greater than the EU's contemporary rate of 0.17% per year. However, there are large uncertainties in projecting afforestation rates.
Compatibility with farming systems	Many farmers need a significant extra incentive to encourage afforestation and to compensate for perceived opportunity costs of

	reducing agricultural production. This incentive may also have to compensate for any loss in land capital values (Bell and Greaves, 2010). It is challenging to make farmers recognise the potential cost savings gained through reductions in their labour requirements by planting more trees. Farming is often more of a lifestyle than a business. This means that farmers are often prepared to devote time to the business without full financial recognition for their work. The average age of farmers is increasing and those nearing retirement are likely to be most willing to recognise the benefits of tree planting in reducing labour requirements (Bell and Greaves, 2010). The required incentives could come from either an increase in forestry margins, a fall in agricultural margins or a combination of the two. Increased forestry margins could arise from: • Reduced planting and establishment costs. • Increased planting and annual grant payment. • Timber values. Decreased agricultural margins could result from: • Reduced market returns. • Reduced subsidy payments. • Increased costs (Bell and Greaves, 2010).
Impact on farm income	Most woodland planting options are not competitive with average agricultural returns under a full-farm-cost scenario except for broadleaved plantings on unimproved land. In reality, however, most farms would be able to reduce operational (labour and machinery) fixed costs over time, as agricultural area fell, through the use of contractors, shedding labour and reducing machinery. Under such a scenario all planting would become competitive on both improved land and unimproved without further improvements in margin except for conifers on improved land (Bell and Greaves, 2010).
Verifiable	Forest information and monitoring systems of Member States differ, having been established in order to meet specific national information needs (e.g. timber stocks, increment, age class distribution, erosion, etc.). In order to allow transnational use of the data collected at regional or national level, consistency and comparability of monitoring is required (SFC, 2010).
Field sampling and testing	National Forest Inventories, which are the main source of forest information, vary considerably, for example with regard to definitions, sampling designs, plot configurations, and estimation methods. These differences compromise the comparability and consolidation of wood and carbon stock estimates, yearly annual increments and in-depth knowledge of European forests (SFC, 2010).
Remote sensing	See above.
Record Inspection	See above.
Other	
Co-benefits	Forests, new shelterbelts, hedgerows, woody buffer strips and in-field trees provide many services. They can: protect biodiversity, enhance water quality, delay and reduce flood flows, prevent landslides, protect landscape values, soil fertility and downstream agricultural land, enhance

	air quality, provide shade and shelter, and prevent erosion caused by wind, water and desertification (SFC, 2010). Afforestation activities can support biodiversity, if they only convert degraded land or ecosystems largely composed of invasive alien species; include native tree species; consist of diverse, multi-strata canopies; result in minimal disturbance, consider the invasiveness of non-native species, and are strategically located within the landscape to enhance connectivity (AHTEGBC, 2009). Reforestation can provide both biodiversity and climate change mitigation benefits if it uses an appropriate mix of native species, incorporates any natural forest remnants, and results in a permanent, semi-natural forest. If appropriately designed and managed, reforestation activities on degraded lands can also relieve pressures on natural forests by supplying alternative sources of sustainable wood products to local communities, thereby providing additional biodiversity and climate change mitigation benefits (AHTEGBC, 2009).
Any adverse environmental impacts	Afforestation that converts non-forested landscapes with high biodiversity values (e.g. heathland, native grassland, savannah) and/or impacts on valuable ecosystem services or increases threats to endemic biodiversity through habitat loss, fragmentation and the introduction of invasive alien species will have adverse impacts on biodiversity (AHTEGBC, 2009). While reforestation with fast‐growing monocultures, often exotics, can yield high carbon sequestration rates and economic returns, it does not benefit biodiversity conservation (AHTEGBC, 2009).
Social acceptance	Forests are individually multi-functional and serve diverse social, environmental and economic functions. In addition to providing raw materials and bioenergy, forests provide people with a wide range of services including places to relax and enjoy. In consequence, the forestry sector provides *c*. three million people with income, mainly in rural areas (SFC, 2010).

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) did not consider afforestation and reforestation. However, they did address the establishment of shelterbelts and hedges to provide multiple adaptation benefits, but not woody buffer strips or in-field trees. They 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.

Conclusions

Afforestation (including new shelterbelts, hedgerows, woody buffer strips and in-field trees) needs to be taken forward as a practical GHG mitigation action. Reforestation does not require further consideration because it is integral part of sustainable forest management and does not, therefore, provide sequestration potential.

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Preventing deforestation and removal of farmland trees

Introduction

Forestry may contribute to GHG mitigation through reducing deforestation and forest degradation. 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).

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).

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) did not consider preventing deforestation.

Indirect effects on GHG emissions (including leakage)

None.

Conclusions

Preventing deforestation does not need to be taken forward as a practical GHG mitigation action.

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

Introduction

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.

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).

Table recording results of the evaluation of Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land

Assessment criteria	Evaluation results
Mitigation potential	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 general, a forest stand acts as a carbon source for some years after final harvesting or thinning. Harvesting at small scales, retaining canopy cover and/or early reforestation can limit loss of carbon. Close-to-nature forestry with longer rotation periods maintains relatively higher soil-carbon stocks. Whole-tree harvesting increases the amount of harvested biomass by up to 40%, but can lead to losses of nutrients, and carbon losses in soil (particularly after stump extraction) and acidification unless appropriately compensated (e.g. through ash recycling). Selection of appropriate species mixtures can increase the overall production of forests. An important objective is to stabilize stands against biotic and abiotic disturbances, for example, to avoid large-scale loss of soil carbon (e.g. from drainage or wild fires) (SFC, 2010). Carbon stocks in EU forests have been increasing in recent decades. Currently, only 64% of Europe's annual growth is harvested. Around 3% of European forests are protected for biodiversity conservation, and 25% of EU forests are excluded from wood harvesting. Forest certification schemes and sustainable forest management are increasingly common. As a result, EU forests are accumulating carbon and currently act as a net carbon sink removing *c*. 0.5 Gt of CO_2/yr. However, the combined effects of climate change, prevalence of older stands and potential increases in timber harvesting without proper regeneration may have an impact on this sink capacity. According to projections up to 2020, EU forests will decline as a carbon sink due to aging stands, and forests in

	some Member States may become net sources by 2020 and beyond (SFC, 2010). Wood produced from sustainable forest management (SFM) in the EU has a low carbon footprint. Wood contains an equivalent of about 0.9 t of CO_2/m^3, which is stored in harvested wood products throughout their lifetime. At the end of their life cycle, most wood products can be recycled, thereby extending the carbon storage effect, and/or used to substitute fossil fuels. A meta-analysis has shown that for each tonne of carbon in wood substituted for non-wood products GHG emissions are reduced by approximately 2.1 tonnes of carbon (Sathre and O'Connor 2010).
How effective is the action across the EU?	Forests are particularly sensitive to climate change because trees' long lifespan does not allow rapid adaptation to environmental changes. European forests are very heterogeneous and SFM that takes due account of climate change mitigation and adaptation is challenging (SFC, 2010).
How sensitive is the action to farmer implementation?	Developing optimal regional strategies for climate change mitigation (in combination with adaptation) involving forests will require analyses of the complex trade-offs and synergies between forests' wide-ranging environmental, economic and social functions. Most notable is the potential conflict between SFM and promoting harvesting for product substitution (SFC, 2010).
Compatibility with farming systems	Location specific, as noted above, only 64% of Europe's annual forest growth is currently harvested.
Impact on farm income	Positive but variable.
Verifiable	Forest information and monitoring systems of Member States differ having been established in order to meet specific national information needs (e.g. timber stocks, increment, age class distribution, erosion, etc.). In order to allow transnational use of the data collected at regional or national level, consistency and comparability of monitoring is required. There is no commonly agreed framework to monitor the forest-wood supply chain in the Member States. Flows along the various product chains are usually based on predetermined ratios, not on observed values (SFC, 2010).
Field sampling and testing	National Forest Inventories, which are the main source of forest information, vary considerably, for example with regard to definitions, sampling designs, plot configurations, and estimation methods. These differences compromise the comparability and consolidation of wood and carbon stock estimates, yearly annual increments and in-depth knowledge of European forests (SFC, 2010).
Remote sensing	See above
Record Inspection	See above
Other	Only broad-brush projections of climate change impacts on European forests are available. The knowledge base needs to be broadened through monitoring, experiments and modelling, including for increased emissions scenarios. Knowledge and projections of impacts need to be regionally specific, and consider relations with forest management, other local factors (including predominant types of forest production,

	disturbances, pests, genetic resources etc.), and address the full range of forests' environmental, social and economic values (SFC, 2010). The role of European forests in the carbon cycle is reasonably understood. However, to what degree SFM can influence the carbon cycle under climate change and how it affects provision of other services remains an important field of research (SFC, 2010).
Co-benefits	SFM maintains forests' multi-functionality through emulating natural processes. It contributes to delivery of the Europe 2020 strategy's objectives, which are to: generate more growth using fewer resources; and achieve a low-carbon economy through sustainable management of natural resources. Sustainable forest management contributes to smart, sustainable and inclusive growth by helping society to mitigate and adapt to climate change (SFC, 2010). In forest landscapes currently subject to harvesting, climate change mitigation, biodiversity conservation and sustainable use can be best achieved by SFM, which takes account of multiple values, appropriate temporal and spatial scales, and suitable rotation lengths. SFM often decreases logging intensities, and minimizes collateral damage to ground cover and soils. The application of internationally accepted principles of SFM in forests that are being degraded by current forestry practices can contribute to climate change mitigation, biodiversity conservation and sustainable use by enhancing carbon stocks and reducing GHG emissions (AHTEGBC, 2009). The conservation of existing primary forests provides important opportunities for protecting carbon stocks, preventing future GHG emissions, and conserving biodiversity. Most of the carbon in a primary forest is stored in older trees or the soil. Land-use activities that involve clearing and logging reduce standing carbon stocks, cause collateral losses from soil, litter and deadwood and reduce biodiversity and thus ecosystem resilience. This creates a carbon debt which can take decades to centuries to recover, depending on initial conditions and the intensity of land use (AHTEGBC, 2009).
Any adverse environmental impacts	If SFM practices are applied to previously intact primary forests, this could lead to increased carbon emissions and biodiversity loss, depending on the specific practices and the forest type (AHTEGBC, 2009).
Social acceptance	Forests are individually multi-functional and serve diverse social, environmental and economic functions. In addition to providing raw materials and bioenergy, forests provide people with a wide range of services including places to relax and enjoy. In consequence, the forestry sector provides *c*. three million people with income, mainly in rural areas (SFC, 2010).

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) did not consider woodland management of existing forests, although they did cover the management of shelterbelts and hedges to provide multiple adaptation benefits, but not woody buffer strips or in-field trees. They 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

- Shelter belts have an impact of +14 kg C/ha/yr.

Conclusions

Conserving existing primary forests provides important opportunities to protect carbon stocks and prevent future GHG emissions. More generally, promoting SFM that provides timber and wood for product substitution and carbon storage in products may be the most important element of forest management to take forward as a practical GHG mitigation action.

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Improving grassland management to increase carbon sequestration

Introduction

This mitigation action is considered with respect to its potential for sequestering C in soil.

The objective of this candidate mitigation action is to increase carbon sequestration in existing grassland soils. The option of converting arable land to grassland in order to sequester carbon in soils is considered as candidate mitigation action 4, 'conversion of arable land to grassland to sequester carbon in the soil'. This candidate mitigation action therefore comprises management options for existing grassland. Soussana *et al*., (2010) report a meta-analysis of 115 studies in pastures and other grazing lands worldwide (Conant *et al*., 2001), which indicated that soil C levels increased with improved management (primarily fertilization, grazing management and improved grass species) in 74% of the studies considered. O'Mara (2012) considered there are a number of practices that could contribute to increasing the carbon content of soils under grazing lands:

Grazing intensity. Both under and over grazing can reduce carbon sequestration or lead to carbon loss from soils.

Increased productivity. Improving the productivity of pastures through practices such as fertilization and irrigation can improve carbon storage in pastures. There can be some offsetting of these gains by N_2O emissions from N fertilizers and the energy used in irrigation.

Nutrient management. A positive correlation between C sequestration and N fertilization has been observed in managed grasslands. Comparisons between management systems have shown that intensively managed grasslands can sequester over 2 tonnes C ha^{-1} $year^{-1}$ more than extensive systems.

Enhancing grass species diversity. In particular, introducing new deep-rooted grasses with greater productivity can increase soil carbon, particularly on low-productivity pastures.

Table recording results of the evaluation of grassland management

Mitigation potential	The increase in carbon sequestration by improved grassland management will vary considerably depending upon: the management practice adopted; previous management; soil type; climate. Reported estimates range from 0 to > 2.0 t C/ha/year (Buckingham *et al.,* 2014).
How effective is the action across the EU?	Likely to vary greatly across the EU depending upon current grassland management practices.
How sensitive is the action to farmer implementation?	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.
Compatibility with farming systems	This will also depend greatly on the management option and the farming system. For example, in some areas of western Europe, with a mild winter climate, cattle farmers have extended the grazing season (adopting practices developed in New Zealand) to reduce costs. Such farmers would be reluctant to revert to a shorter grazing season. Conversely, some dairy farmers are reducing the amount of time spent grazing in order to provide higher-energy diets, generally providing a greater proportion of maize-

	based silage, in order to increase milk yield. Moves to reduce early- or late-season grazing would fit well with such systems.
Impact on farm income	In many cases, improved grassland management may lead to a net increase in farm income as a result of using inputs more efficiently but on farms with a high stocking rate costs may increase if more feed needs to be imported.
Verifiable	Verification would be difficult as it would need to be specific to the management practice and farm type.
Field sampling and testing	Field sampling is possible but would be expensive as sampling would need to be to at least 90 cm depth and on an equivalent mass basis.
Remote sensing	Not appropriate.
Record Inspection	Probably the best means of monitoring uptake of appropriate actions.
Other	
Co-benefits	Increasing soil carbon, and thereby increasing soil organic matter, will improve soil structure. This will therefore reduce the risk of soil damage from machinery and livestock and reduce the risk of soil erosion.
Any adverse environmental impacts	Increasing inputs to increase grass production and thereby increasing carbon returns to the soil, may lead to increases in other emissions, especially NO_3^- and ammonia (NH_3).
Social acceptance	This is likely to depend upon the change in management practice and the locality where the change is introduced.

Ecologic evaluation

This potential mitigation action was not assessed in the Frelih-Larsen *et al.,* (2014) report.

Key points

Factors influencing carbon sequestration

Soussana *et al.,* (2010) proposed the following options to increase C storage on existing grassland:

1. Reducing N fertilizer inputs in highly intensive grass leys
2. Increasing the duration of grass leys
3. Converting these leys to grass-legume mixtures or to permanent grasslands
4. Moderately intensifying nutrient-poor permanent grasslands

By contrast, the intensification of nutrient-poor grasslands developed on organic soils may lead to large C losses, and the conversion of permanent grasslands to leys of medium duration is also conducive to the release of soil C.

- In mineral soils, fertilization of grassland is generally considered to enhance C storage due to enhanced productivity (O'Mara, 2012). A positive correlation between C sequestration and N fertilization has been observed in managed grasslands (Jones *et al*., 2006). Sousanna *et al*., (2004) stated that N fertilization may increase net ecosystem production in moderately fertile systems, as the increase in production outweighs any concurrent increase in decomposition. In more organic-rich mountain pastures, due to the relatively large pool of organic matter available for decomposition, N fertilization may trigger large carbon losses. Morris *et al*., (2010) reported that 'semi intensive' grassland farming, with moderate levels of mineral and organic fertilizer, could offer a commercially feasible peatland 'conservation and carbon storage' option, especially in dairy areas, with modest returns of £50- £200/ha. This would require high standards of management in order to meet environmental objectives. The 'opportunity cost' of taking land out of agricultural production is likely to reduce over time as peatlands are degraded and become less agriculturally productive. 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).

- Irrigating grasslands, similarly, can promote soil C gains (O'Mara, 2012).

Enhancing species diversity and, in particular, introducing new deep-rooted grasses with greater productivity into the species mix has been shown to increase soil carbon, particularly on low-productivity pastures (Tilman *et al*., 2006).

The uncertainties concerning the estimated values of C storage or release after a change in grassland management are still very high (estimated at 25 g C/m^2 per year).

Applicability

The applicability of this mitigation action to an individual farm will depend upon the extent to which the farm currently applies best management practice with respect to sequestering carbon in soil.

Timescale over which mitigation action becomes effective and duration

The timescale will vary according to the changes made to the grassland management system.

Leakage (production displacement)

If changes to grassland management lead to reduced production within the EU, there could be some switch in production to regions where emission intensity is greater. The likelihood of this risk will depend upon the management practice adopted.

Conclusions

This mitigation action has potential for adoption in the CAP in order to reduce emissions of GHGs. The action will need to be implemented on a farm by farm basis so that actions supported by CAP are in addition to current management practices.

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Use of grasslands to reduce fire risk

This mitigation action was not evaluated as there were insufficient data to screen this potential action.

Reduced tillage

Introduction

In this assessment 'Reduced tillage' (RT) is used to describe all non-plough based cultivation practices. This mitigation action is considered with respect to its potential for sequestering carbon (C) in the soil. 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. There are very 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.

Table recording results of the evaluation of reduced tillage

Mitigation potential	Depends upon the impacts on crop yields. Only where crop yields are increased by the introduction of RT is C sequestration likely to occur. *Where RT does sequester C, the practice needs to be maintained as even only occasional cultivation can release the C sequestered in previous years.*
How effective is the action across the EU?	In most EU regions, crop yields are likely to be similar or less with RT than from conventional tillage (CT) and hence the action will not be effective. In dry areas, where crop yields can be increased by RT, there can be net C sequestration in soils. In addition, emissions of nitrous oxide (N_2O) are less likely to be increased by RT in dry areas. However, the exact amounts are difficult to quantify as they will vary according to the crops grown and the soil type.
How sensitive is the action to farmer implementation?	There are several options for reduced tillage and the choice and application of method is likely to influence the outcome. There are a great many approaches to reduced tillage and not all have been evaluated for C sequestration. All approaches will involve replacing ploughing with non-inversion methods of cultivation.
Compatibility with farming systems	Generally less compatible with farming systems in high rainfall areas where yields, and crop residues are large. Generally better suited to self-structuring soils with significant clay content than to sandy soils. Poor weed control in the long term is one of the main issues with this mitigation action. Most suitable to semi-arid areas.
Impact on farm income	This mitigation action can offer cost savings from a reduction in the number of cultivations in all areas.
Verifiable	Difficult, see comments below.
Field sampling and testing	Soils need to be sampled to at least 1 m, and a rigorous protocol, including taking bulk density samples, needs to be followed. Verification by direct soil sampling is likely to be too expensive and subject to large uncertainties. Modelling soil C will be a less expensive option but is also subject to uncertainties.
Remote sensing	May record the action but not the impact on soil organic C (SOC).

Record Inspection	May record the action but not the impact on SOC.
Other	Perhaps an approach using modelling supplemented by soil sampling would be the most cost-effective and reliable method of verification.
Co-benefits	Reducing cultivation saves costs by reducing labour and fuel inputs and by reducing wear on machinery. The size of these cost reductions will depend on the extent to which the number of cultivations is reduced. In some cases the reduction in tillage operations, and hence cost, will be small. Can be an effective means of reducing soil erosion. Conserves moisture in semi-arid areas.
Any adverse environmental impacts	Reduced tillage may increase the use of herbicides to kill weeds that would otherwise be controlled by ploughing and may require increased application of slug pellets. There can also be increased carry-over of fungal disease from crop residues left on the soil surface.
Social acceptance	Likely to be acceptable as, in addition to the reduction in erosion, reducing cultivation will reduce dust formation during dry weather. However, reducing labour requirements may be less acceptable if it leads to fewer jobs; especially in areas where there are few other sources of employment.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) did not evaluate RT.

Key points

Impact of reduced tillage on crop yields

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.

Leakage (production displacement)

Adoption in regions or in cropping systems in which yield is reduced (Van den Putte *et al.,* 2010) would lead to increased production elsewhere, possibly in regions where GHG emissions per tonne of crop produced are greater than in the EU.

Conclusions

The large range of cultivations that can be considered as RT makes a balanced comparison of C sequestration by RT with CT very difficult. Nevertheless, the lack of consistent evidence to indicate that RT sequesters C in soils leads us to recommend that this mitigation action is not considered further.

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Zero tillage

Introduction

This mitigation action is considered with respect to its potential for sequestering carbon in the soil.

Zero tillage (ZT), is the elimination of all soil tillage. Seed is drilled directly into an uncultivated soil or simply broadcast onto the soil surface. Although ZT has been advocated as a means of sequestering soil C, more recent reviews and meta-analyses have concluded that, in many cases, ZT alters the distribution of C within the soil profile but does not change the total amount of C in soil. Exceptions occur when:

- The adoption of ZT 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 ZT. Again, this increases total dry matter production and can increase soil C as a result of increased crop residue returns.

Table recording results of the evaluation of zero tillage

Mitigation potential	Depends upon the impacts on crop yields. Only where crop yields are increased by the introduction of ZT is C sequestration likely to occur. *Where ZT does sequester C, the practice needs to be maintained as even only occasional cultivation can release the C sequestered in previous years.*
How effective is the action across the EU?	In most regions, crop yields are likely to be similar or less than from CT and hence the action will not be effective. In dry areas, where crop yields can be increased by ZT, 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.
How sensitive is the action to farmer implementation?	Zero-tillage is a fairly clear action likely to be implemented consistently.
Compatibility with farming systems	Zero tillage is generally less compatible with farming systems in high rainfall areas where yields and crop residues are large. This mitigation action is generally better suited to self-structuring soils with significant clay content than to sandy soils. Most suitable to semi-arid areas.
Impact on farm income	This mitigation action can offer cost savings from reduction in the number of cultivations in all areas.
Verifiable	Can be verified from farm records.
Field sampling and testing	Difficult; soils need to be sampled to at least 1 m and a rigorous protocol, including taking bulk density samples, needs to be followed. Verification by direct soil sampling is likely to be too expensive and subject to large uncertainties.
Remote sensing	Unlikely that it will be possible to distinguish ZT fields from those conventionally cultivated.

Record Inspection	It will be possible to confirm implementation of action from farm records.
Other	Modelling soil C will be a less expensive option but will also be subject to uncertainties.
Co-benefits	Reducing cultivation saves costs by reducing labour and fuel inputs and by reducing wear on machinery. Can be an effective means of reducing soil erosion. Conserves moisture in semi-arid areas.
Any adverse environmental impacts	Zero tillage may increase the use of herbicides to kill weeds otherwise controlled by ploughing and may require increased application of slug pellets. There can also be increased carry-over of fungal disease from crop residues left on the soil surface.
Social acceptance	Likely to be acceptable as in addition to the reduction in erosion, reducing cultivation will reduce dust formation during dry weather. However, reducing labour requirements may be less acceptable if it leads to fewer jobs, especially in areas where there are few other sources of employment.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) acknowledged the growing evidence that ZT leads to little or no C sequestration. Frelih-Larsen *et al.,* (2014) emphasise the other potential benefits of ZT:

- Soil quality improvement
- Saving in fuel and labour
- Reduction in soil erosion
- Increase biodiversity (soil microorganism)
- Better water efficiency/quality

Key points

Mechanisms that lead to SOC accumulation

A consideration of the mechanisms that lead to SOC accumulation suggest reasons why ZT might increase SOC (increased mycorrhizal activity) but also reasons why ZT might reduce SOC (incorporating crop residues is more effective at producing stable SOC than leaving residues on the surface).

The impact of zero tillage on crop yields

This will be a major reason why so many studies have found no net C sequestration from either RT or ZT.

A review of European studies indicated that there was a mean yield reduction of 8.5% from ZT (compared with a mean yield reduction of 4.0% for RT) (Van den Putte *et al.,* 2010), while Soane *et al*., (2012) reported yield reductions of 5 to 10% for northern Europe but for SW Europe yields were similar. *A strong correlation was observed between yield and precipitation during the wheat cycle. Regression lines crossed at 300 mm of growing season rainfall, a point at which below ZT was superior to CT and at which above CT was superior to ZT*. A study in Spain, by Ordónez Fernández *et al.,* (2007), found that zero tillage resulted in greater yields than conventional tillage in dry conditions, but not in wet conditions. Similar results were obtained in southern Italy by De Vita *et al.,* (2007). Yield loss in Sweden (Arvidsson *et al.,* 2014) was greater for spring than for autumn-sown crops. Yield reductions were associated with disease carryover and poor establishment (losses greater following cereals than following OSR or peas) rather than compaction.

The impact of zero tillage on yield varies among crops

Yields of soybeans were not decreased (Alvarez and Steinbach, 2009) and in some cases significantly increased by ZT (Franchini *et al*., 2012). But yields of maize and wheat could be decreased by ZT when N fertilizer was limiting (Alvarez and Steinbach, 2009) but similar when the N supply was adequate.

Leakage (production displacement)

Adoption in regions or in cropping systems in which yield is reduced (Van den Putte *et al.,* 2010) would lead to increased production elsewhere, possibly in regions where GHG emissions per tonne of crop produced are greater than in the EU.

Changes in tillage practice and residue treatment are often confounded. Hence it is difficult to identify the mechanism by which C may be sequestered.

For example, in Mediterranean conditions, ZT is often associated with straw retention, whereas when soils are tilled, residues are removed (Lopez-Bedillo, *et al.,* 2010).

For this reason the impacts of leaving crop residues on the soil surface are considered as a separate mitigation action.

Conclusions

Manley *et al.,* (2005): 'Our statistical analyses of more than 100 studies and some 900 estimates suggest that, compared to CT, ZT seems to sequester too little carbon at too high a cost to make this means of mitigating climate change an attractive alternative to emissions reduction. *However, there are some exceptions where an effort to switch from conventional to no till agriculture does lead to a low-cost carbon benefit*'. Nevertheless, even in locations where ZT can increase soil C, it needs to be maintained. This can be difficult and ZT can lead to build up of weeds which can only be controlled by cultivation. The recent review by Buckingham *et al*., (2014) concluded that ZT will only sequester C in soils when crop yields are increased, e.g. by eliminating the need for fallow to conserve moisture and hence enabling a crop to be grown every year.

We therefore do not consider that this mitigation action should be considered further as an option to reduce GHG emissions from agriculture. It may be worthwhile to consider adoption into CAP for other reasons, e.g. erosion control.

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Leaving crop residues on the soil surface

This mitigation action is considered with respect to its potential for sequestering C in the soil.

Table recording results of the evaluation of leaving crop residues on the soil surface

Mitigation potential	The greater the crop yield, the more residues will be available and the greater the C sequestration potential will be. Alternative uses for crop residues, e.g. biofuels, may reduce the amount of resource available. In most regions, crop yields are likely to be similar or slightly less than if crop residues were removed, but soil C will increase due to the addition of the residues. 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.
How effective is the action across the EU?	This action should be effective across all regions.
How sensitive is the action to farmer implementation?	Either the action is carried out or it is not, so implementation should be consistent.
Compatibility with farming systems	Generally less compatible with farming systems in high rainfall areas where yields and crop residues are large. Care needs to be taken to avoid inhibiting germination of small-seeded crops. There are also microclimatic effects of mulch (e.g. suppression of temperature) which may reduce the effective growing season and issues associated with pest control (e.g. slugs). Even spreading is necessary to minimise risks of reduced crop emergence or poor weed control. Conservation of soil moisture in the root zone by residue mulch is an advantage in arid and semi-arid climates.
Impact on farm income	Variable. Savings in costs, mainly labour, can be greater than reductions in income from reduced yield. The balance is most likely to be favourable where labour costs are greatest and where there is potential for increased crop yields.
Verifiable	
Field sampling and testing	Difficult; soils need to be sampled to at least 1 m, and a rigorous protocol, including taking bulk density samples, needs to be followed. Verification by direct soil sampling is likely to be too expensive and subject to large uncertainties.
Remote sensing	It may be possible to distinguish fields where crop residues have been left on the soil surface from those where residues have been removed.
Record Inspection	It will be possible to confirm implementation of action from farm records.

Other	Modelling soil C will be a less expensive option but also subject to uncertainties.
Co-benefits	Leaving crop residues on the soil surface can save costs by reducing labour and fuel inputs and by reducing wear on machinery. Can be an effective means of reducing soil erosion. Conserves moisture in semi-arid areas.
Any adverse environmental impacts	Leaving crop residues on the soil surface may require increased application of slug pellets. There can also be increased carry-over of fungal disease from crop residues left on the soil surface.
Social acceptance	Likely to be acceptable where the mitigation action reduces erosion. Reducing labour requirements may be less acceptable if it leads to fewer jobs, especially in areas where there are few other sources of employment.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) concluded that retaining crop residues can mitigate GHG emissions in four main ways:

- Reducing direct emissions from N fertilizers
- Reducing the CO_2 emissions from fertilizer manufacture
- Increasing carbon sequestration
- Reducing the amount of N that needs to be applied to the following crop

Key points

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.

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 CT was compared with ZT systems. Microbial biomass C was found to be greater under CT than ZT 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 CT than ZT 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).

Trigalet *et al.,* (2014) found that residue management can increase the storage of C in more stable fractions in agricultural soils, even when no changes are detected in bulk soil C.

The greatest potential soil C sequestration from returning cereal straw will be in those regions where cereal yields are greatest (Lugato *et al.,* 2014).

Leakage (production displacement)

Returning crop residues to soil does not appear to pose the risk of significant leakage.

Conclusions

We recommend this mitigation action be considered further for inclusion in the CAP as a GHG mitigation option.

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Ceasing to burn crop residues and vegetation

Introduction

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

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'.

Table recording results of ceasing to burn crop residues and vegetation

Assessment criteria	**Evaluation results**
Mitigation potential	'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. A further statistic is that 0.1% of N_2O sources in the United States are from field burning (Johnson *et al.,* 2007). In contrast, it is stated by Eurostat (1999) that 'In Western Europe, it is assumed that emissions of CO_2 due to burning agricultural waste are part of a cycle, with emissions being reabsorbed by an equivalent amount by crops and vegetation regrowing in the following season. Therefore net emissions are considered to be zero'. 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 amount of these gasses being produced. Yokelson *et al.,* (2011; cited in Thangarajan *et al.,* 2013) also stated that burning of crop residues results in GHG emissions; therefore again we would expect a reduction of GHG emissions when burning of crop residues was ceased. 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} $year^{-1}$'. Worrall *et al.,* (2010; cited in Bell *et al.,* 2014) stated that with the cessation of managed burning, C sequestration will occur in grasslands.
How effective is the action across the EU?	This will be most effective in those regions where significant amounts of crop residues are still burned.
How sensitive is the action to farmer implementation?	There should be little sensitivity: residues will be burned or they will not.
Compatibility with farming systems	There has been a preference, for some farming systems to burn residues rather than incorporate them into soil, mainly to reduce cultivations and improve seedbed quality. However, in MSs where the practice has been banned farmers have been able to adapt to new practices.

Impact on farm income	Unlikely to affect farm income unless crop residues are being sold as a biofuel feedstock.
Verifiable	Should be verifiable from field inspection.
Field sampling and testing	NA
Remote sensing	Should be verifiable from aerial surveys.
Record Inspection	This should be verifiable from farm records.
Other	
Co-benefits	The health effects associated with burning of crop residues – emissions of PM2.5 resulting in children and adults suffering more severe and frequent asthma attacks – are eliminated when crop residues are no longer burnt (McCarty *et al.,* 2009). Not only does this particulate matter and trace gas emissions associated with burning of crop residues lead to adverse health effects but they also reduce air quality (McCarty *et al.,* 2009). Additionally, ceasing burning vegetation and crop residues results in a reduction in soot, smoke and particulate matter (Estrellan and Lino, 2010). If residues are not burnt in the field, they can be collected and used for energy production (Reijnders, 2008). Complementary changes to crop management may occur as a result of ceasing to burn crop residues; farmers may instead retain these as a mulch (Erenstein, 2003).
Any adverse environmental impacts	As burning can be an inexpensive means to control insects, disease, and the emergence of invasive weed species, there may be an increase in herbicide and pesticide use.
Social acceptance	Lower public health problems and better air quality would imply that this measure would have social acceptance.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) did not evaluate this option.

Key points

Below-ground biomass is not affected by burning of crop residues (Toma *et al.,* 2010; cited in Dufosse *et al.,* 2014).

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'.

Leakage (production displacement)

Ceasing to burn crop residues is unlikely to reduce output and displace production elsewhere.

Conclusions

It is stated in Estrellan and Lino (2010) that 'data from simulated and in situ open burning experiments of various agricultural product residues such as rice, wheat, sugar cane and other crops showed a variety of emissions such as soot and particulate matter (PM), CO, CH_4, and volatile organic compounds. More recently, polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzo-p-dioxins, and polychlorinated dibenzofurans (PCDD/Fs) have been reported to have been detected in gaseous phase emissions, in the particulate matter, and in the residual ash, along with ionic species, elemental carbon (EC), and organic carbon (OC)'. This demonstrates that ceasing to burn crop residues brings many benefits in the way of reducing GHGs emitted and also in terms of reducing the amount of soot and PM released into the air; consequently having additional beneficial impacts on health.

It is difficult to find quantifiable estimates of the reduction in GHG emissions.

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Use cover/catch crops

Introduction

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

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).

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).

Table recording results of the evaluation of using cover/catch crops

Assessment criteria	Evaluation results
Mitigation potential	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). This is supported by Poeplau and Don (2015) who 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; 'we comprised the majority of available cover crop studies worldwide and 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}'. 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). Iqbal et al. (2015) cited the review of Basche et al. (2015) of the impact of cover crops on N_2O emissions which reported 60% of studies found that cover crops increased N_2O emissions while 40% decreased them.
How effective is the action across the EU?	'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.
How sensitive is the action to farmer implementation?	It is stated in Thorup-Kristensen *et al.,* (2003; cited in Gabriel *et al.,* 2013a) that the adoption of cover crops by farmers is limited. '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' (Frelih-Larsen *et al.,* 2014). Potential barriers to uptake include concerns about herbicide use and resistance and the possibly negative affect of the yield of the following crop (Frelih-Larsen *et al.,* 2014).
Compatibility with farming systems	• '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. • Cover crops are more suitable where there is a relatively high spring rainfall as the cover crop will deplete soil moisture reserves and, hence, where there is insufficient rainfall, the main crop can suffer (Dabney *et al.,* 2001). • Cooler soil temperatures under cover crop residues can retard early growth of subsequent crops grown near the cold end of their range of adaptation (Dabney *et al.,* 2001).' This is all cited within Frelih-Larsen *et al.,* (2014). In dry regions, the uptake of this measure has been limited in the past due to unsuccessful establishment and low water use efficiency (Unger and Vigil, 1998; cited in Gabriel *et al.,* 2013a). In dry regions, if not killed at the right time, cover crops can compete against the cash crop for nutrients and water (Gabriel *et al.,* 2013b). This is supported by Hiltbrunner *et al.,* (2007) who state that competition can develop

	between the crop and the cover crop if the dry matter of the cover crop becomes too large. Cover crops may be particularly useful in organic systems as a way of recycling N within the cropping system; they may also help increase N use efficiency in such systems (Li *et al.,* 2014). 'Cover crops are becoming increasingly popular in perennial agroecosystems like vineyards as a way to minimize erosion and increase SOM' (Steenwerth and Belina, 2008).
Impact on farm income	This measure may reduce the costs of weed control and fertilizer/herbicide. Cover crops have the potential to increase the yield of the following crop, and therefore profits, through N fixation. However, there are costs of this measure; for example, there may be a cost forgone of producing a cash crop, cost of seed, establishment, increased field operations, harvesting, killing, and sometimes new equipment may also be required (Gabriel *et al.,* 2013a). Establishing a cover crop involves an extra expense over leaving a field fallow (Gabriel *et al.,* 2013a); 'The extra cost of CC was €67.91 ha^{-1} for barley, €72.70 ha^{-1} for rapeseed, and €71.65 ha^{-1} for vetch when the residues were left in the field. When CC biomass was lifted and sold as animal feeding the extra cost of CC was reduced to €27.91 ha^{-1} for barley, €32.70 ha^{-1} for rapeseed, and €31.63 ha^{-1} for vetch' (Gabriel *et al.,* 2013a). However, these costs do not take into account fertilizer savings – see Gabriel *et al.,* (2013a) for these figures and more detail. Growing cover crops in a rotation with vegetable crops is described by Wells *et al.,* (2000) as a way to 'optimize profit while minimising environmental impact'.
Verifiable	
Field sampling and testing	Verifiable by field visits to identify standing crop(s) and assess ground cover by the crop.
Remote sensing	Images could be used to determine extent of ground cover at intervals through the year.
Record Inspection	Verifiable through farm records of field operations
Other	
Co-benefits	Cover and catch crops are efficient at reducing N leaching (Gabriel *et al.,* 2013a; Gabriel *et al.,* 2013b; Abdalla *et al.,* 2014; Li *et al.,* 2014). In a paper by Constantin *et al.,* (2010) catch crops decreased N leaching by between 36% and 62%; it was argued here that establishing catch crops is the 'most efficient way to decrease the N leaching and to maintain long-term nitrate concentrations below 50 mg L^{-1}'. This is supported by Tonitto *et al.,* (2006; cited in Li *et al.,* 2014) who state that systems with legume based catch crops, compared with fertilizer-based systems, reduce NO_3^- leaching by an average of 40%. However, it is noted by Askegaard *et al.,* (2011; cited in Li *et al.,* 2014) that the increase in soil fertility associated with the long-term use of legume based catch crops may result in increased risks of N leaching. Leguminous cover crops can also fix large amounts of N; this can supply N to the next crop and hence may boost its yield (Erenstein, 2003; Brozyna *et al.,* 2013). However, if the cover crop is harvested and not

	returned to the soil, there may be a smaller benefit, or no benefit of increased yield (Li *et al.,* 2014). Askegaard and Eriksen (2007) and Doltra and Olesen, (2013; both cited in Brozyna *et al.,* 2013) found typical autumn values for above-ground N in cover crops to be 20 to 60 kg N ha^{-1}. This may enable leguminous cover crops to act as an alternative to N fertilizer in some cases (Erenstein, 2003). Cover crops have the additional benefits of preventing water and wind erosion, enhancing nutrient efficiency, decreasing soil decomposition rates, increasing water use and correcting saline soil (Gabriel *et al.,* 2013b; Abdalla *et al.,* 2014; Poeplau and Don, 2015). Their protective layer also means that soils are kept drier for longer in wet climates (Desjardins *et al.,* 2005; Reicosky and Forcella, 1998; both cited in Abdalla *et al.,* 2014). Furthermore, cover crops can assist in pest and weed control (Erenstein, 2003; Poeplau and Don, 2015). Catch crops are described by Constantin *et al.,* (2010) as a 'win/win technique with respect to nitrate leaching and C and N sequestration in soil'. However, a study by Bavin *et al.,* (2009) indicates that there is limited potential for carbon sequestration through the use of spring cover cropping, unless residue is removed. Palese *et al.,* (2014) stated that due to improved soil structure and the presence of vegetation, cover crops are able to increase soil water storage. However, this effect trades off against greater evapotranspiration from a cover crop compared with bare fallow (Dabney *et al.,* 2001; cited in Frelih-Larsen *et al.,* 2014). Cover crops can increase biodiversity (Lal, 2004; cited in Poeplau and Don, 2015). Soil ammonium is greater in systems with cover crops than those under cultivation (Steenwerth and Belina, 2008). Lehman *et al.,* (2012) demonstrated that the mycorrhizal inoculum potential of the soils was increased substantially by autumn cover crops.
Any adverse environmental impacts	The removal of cover/catch crops by pesticides may decrease water quality (Ferrant *et al.,* 2013).
Social acceptance	No reports were found concerning the social acceptability of cover crops. There may, however, be effects through changes in farm income. Furthermore, decreases in nitrate leaching may improve drinking water quality, with social benefits.

Ecologic evaluation

There was thorough examination of this measure in the Ecologic report.

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), and protecting against the future increased risk of flooding (Frelih-Larsen *et al.,* 2014).

'Cover crops can mitigate GHG emissions in four main ways:

- Increase of soil organic carbon content.
- Decrease soil erosion during the fallow period.
- Reduction in N leaching.
- Reduction in the amount of N that needs to be applied to the following crop'.

Indirect effects on GHG emissions (including leakage)

In most situations there will be no leakage (displacement of production) because there is no negative effect on production in well-managed systems.

Conclusions

Cover crops can reduce GHG emissions and provide many other environmental benefits, however the amount of mitigation seen is largely dependent on how the crop is utilised – e.g. whether it is used in anaerobic digestion, used as a fertilizer or mulched. It is suggested by Steenwerth and Belina (2008) that the potential increase in N_2O emissions needs to be evaluated taking into account the range of benefits associated with cover cropping. Whilst a slight increase in GHG emissions may be seen with the use of this measure, in particular in spring, it is generally accepted that the benefits of increased SOC and N fixation offset this increase.

'The advantage of cover crops as compared with other management practices that increase soil organic carbon (SOC) is that they neither cause a decline in yields, like extensification, nor carbon losses in other systems, like organic manure applications may do' (Poeplau and Don, 2015).

Overall, we recommend that use of cover crops is taken forward as a practical GHG mitigation action.

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Biochar applied to soil

Introduction

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

Definitions of biochar vary widely, and can include criteria related to physical properties, particle size, chemical properties, feedstock material, and sustainability characteristics of the production feedstock. Because of the wide range of definitions, we do not attempt to present a consensus, which is lacking. Broadly, biochar is a form of charcoal, produced from biomass by pyrolysis.

Biochar can be added to soil, where it amends the soil properties, and is a carbon store.

Mitigation potential may arise through several mechanisms, including increased crop yields, effects on the N cycle and N_2O emissions, carbon storage in soil, and more efficient use of mineral nutrients. There is much recent research published, and many claims, and counter claims, for mitigation potential.

There is evidence of positive effects on yield and reductions of N_2O emissions, but these effects are not well understood at the soil process level.

Table recording results of the evaluation of biochar application

Assessment criteria	**Evaluation results**
Mitigation potential	At present there is no consensus from the data on the realistic mitigation potential. The impact on direct GHG emissions and removals from farming systems is mainly through changes in soil emissions of N_2O and CH_4 (Smith *et al.,* 2014). A meta-analysis has shown a mean decrease of 54% in N_2O emissions from biochar-amended soils (Cayuela *et al.,* 2014). However, much of the understanding of interactions between biochar and the soil N cycle comes from laboratory studies and these interactions are not predictable, especially under field conditions (Smith *et al.,* 2014). Biochar has been shown to increase CH_4 oxidation in soil (Schimmelpfennig *et al.,* 2014), thereby decreasing CH_4 emissions; however, there were large interactions with other factors (e.g. application of slurry), and other forms of carbon addition to the soil had similar effects. Potential beneficial effects of biochar soil amendment on GHG emissions must be viewed in the context of trade-offs against indirect increases in GHG emissions (carbon leakage, see below), and the carbon balance of associated activities such as energy generation during pyrolysis.
How effective is the action across the EU?	The potential effectiveness of this action varies with soil type, and therefore will vary geographically. Benefits reported in experimental studies are likely to be realisable across the EU, where the farming system allows incorporation into soil. The mechanism of the mitigation potential will vary with soil type.
Effect of variation in farmer implementation?	Implementation may be varied by using different materials (e.g. biochar made from different feedstocks and with different particle size distributions), by incorporating differently (e.g. depth and extent of mixing), by the quantity applied, and by the land use.

Compatibility with farming systems	Compatible with farming systems that include soil cultivation to allow incorporation.
Impact on farm income	Highly variable and depends on effects on crop yields and demand for inputs. At present these cannot be forecast with any certainty.
Verifiable	Field sampling and testing: • Verifiable by soil sample and analysis Record Inspection: • Verifiable through farm records of applications
Co-benefits	The biochar production process yields energy.
Any adverse environmental impacts	A large area of land would be needed to supply sufficient biochar feedstock for widespread implementation of the action. This will take land from food production or from provision of other ecosystem services, with potential for many adverse environmental impacts including biodiversity loss and GHG emissions from indirect land use change. The following environmental issues of concern, related to the application of biochar to soil, are listed by Camps Arbestain *et al.,* (2014): • unbalanced addition of nutrients to soil • possible negative impact on soil biota • expected sorption of residual herbicides and pesticides and subsequent implications in the efficiency of these products • potential addition of heavy metals, PAHs and dioxins along with biochar • environmental pollution from dust, erosion and leaching of biochar particles • aerosol emissions during improper pyrolysis • effect on soil surface albedo
Social acceptance	Unclear. There could be large social changes through change of land use for biochar production processes.

Ecologic evaluation

This action is not addressed in the Ecologic report (Frelih-Larsen *et al.,* 2014).

Key points

Effectiveness (compared with current emissions) at a landscape scale

The effects at a landscape scale are unclear because of uncertainty about indirect effects (see below). Experimental data indicate the potential for decreases in GHG emissions in some landscapes (those dominated by crop production in cultivated soils; see section above on impact of biochar application on direct GHG emissions and removals). However, there is potential for increased GHG emissions in some landscapes through indirect land use change as a consequence of direct land use change for biochar feedstock production (see section below on indirect effects on GHG emissions). The balance between direct decreases and indirect increases in emissions is highly uncertain.

Indirect effects on GHG emissions (including leakage)

Of major importance is the area of land that would be needed for biochar feedstock production. There is much conflicting literature on this subject, and we have not found good estimates that are independent of interests in commercial development of biochar.

The quantity of biochar needed to materially influence GHG emissions depends on the half-life of the biochar in soil, and this is likely to be variable and, overall, is not known. Biochar may also influence breakdown of other soil organic carbon (e.g. humus; Kleiner, 2009), which would counteract sequestration of carbon through the long-term persistence of biochar.

Biochar can be produced using crop residues and waste materials (e.g. forest residues), but it is not clear how much material from these sources could be available for biochar production.

Conclusions

Use of biochar on a landscape scale is a long-term possibility, as the required infrastructure and feedstock supply are not in place for immediate implementation. Furthermore, there are large uncertainties in the outcomes for GHG emissions. Further research and field testing is needed to increase the understanding of the overall effects on GHG emissions, alongside other effects on the environment.

Overall, we recommend that application of biochar is not taken forward as a practical GHG mitigation action within the current period of CAP policy (2014 to 2020).

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Extend the perennial phase of crop rotations

Introduction

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

The Ecologic report (Frelih-Larsen *et al.,* 2014) describes this action as "incorporating 1–3 years of a perennial crop (often alfalfa or grass hay) into annual crop rotations".

Table recording results of the evaluation of extending the perennial phase of crop rotations

Assessment criteria	Evaluation results
Mitigation potential	Estimates of mitigation potential are given in Frelih-Larsen *et al.,* (2014) as a range of 0 to 1.2 t CO_2 ha^{-1} yr^{-1}, for carbon sequestration in soil, and a saving of 0.7 t CO_2e ha^{-1} yr^{-1} from other sources such as fertilizer N, field operations, and N_2O emission from soil. However, it is not made 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. Franzluebbers *et al.,* (2014) provide evidence that inclusion of perennial forage crops in a rotation, compared with a rotation that did not include a perennial crop, has a long-term benefit of increased SOC over several rotations, i.e. the benefit was maintained beyond the duration of the perennial crop.
How effective is the action across the EU?	This action is effective in areas with farming systems under annual soil cultivation, and with a use for perennial crops for energy or livestock grazing. Thus, effectiveness will be limited in areas with few livestock and no demand for perennial energy crops.
How sensitive is the action to farmer implementation?	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; more N fertilizer leads to greater biomass production). Plant density (sowing rate) is another implementation factor that influences effectiveness, with denser crop stands likely to provide greater soil carbon sequestration.
Compatibility with farming systems	Farming systems will need to change, e.g. a move from specialist arable farming to mixed arable and livestock farming, to provide a use for perennial crops). This conflicts with trends towards more specialised farming systems over recent decades.
Impact on farm income	Market drivers will affect prices of annual and replacement perennial crop products, and these are difficult to predict. There are savings in cultivation/input costs for perennial crops compared with annual crops, with values highly dependent on the detail of implementation method (crop types, share of land in perennial crops). The specialisation of modern agriculture suggests that there is an economic disincentive for greater diversity of land use.
Verifiable	

Field sampling and testing	Verifiable by field visits to identify standing crop(s).
Remote sensing	Images could be used to determine ground cover and crop type at intervals through the year.
Record Inspection	Verifiable through farm records of field operations.
Other	
Co-benefits	Based on the Ecologic report (Frelih-Larsen *et al.,* 2014): • Biodiversity increase as a result of crop diversity increase. • Less soil erosion. • Better water infiltration and storage in soil. • Decrease in environmental load from nutrients and pesticides.
Any adverse environmental impacts	There are potentially large emissions of GHGs from crop displacement (leakage). See section below on indirect effects.
Social acceptance	Greater diversity of land use is likely to improve provision of some ecosystem services (e.g. biodiversity), suggesting that this action is socially acceptable. However, social acceptance will also be influenced by effects on farm income (see above).

Ecologic evaluation

The Ecologic report (Frelih-Larsen *et al.,* 2014) covers this action and describes it as: "incorporating 1–3 years of a perennial crop (often alfalfa or grass hay) into annual crop rotations". The five main ways that Perennial crops can mitigate GHG emissions are given as follows:

1. Sequestering C to soil.
2. Reducing direct emissions from N fertilizers.
3. Reducing the CO_2e emissions from fertilizer manufacture.
4. Reduction in N leaching.
5. Reduction in the amount of N that needs to be applied to the following crop.

Estimates of mitigation potential are given as a range of 0 to 1.2 t CO_2 ha^{-1} yr^{-1}, for carbon sequestration in soil, and a saving of 0.7 t CO_2e ha^{-1} yr^{-1} from other sources such as fertilizer N, field operations, and N_2O emission from soil. However, it is not made 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.

Key points

Impact on direct GHG emissions and removals

See section above (Ecologic report).

Effectiveness (compared with current emissions) at a landscape scale

This action is likely to be effective at a landscape scale in areas where the action can be widely implemented.

Indirect effects on GHG emissions (including leakage/crop displacement)

Indirect effects are expected through crop displacement (leakage). The magnitude of indirect emissions will depend on the extent to which the market demands products from displaced crops (our review has not found predictions).

There may also be negative leakage through a smaller area of perennial crops grown in other locations. However, many livestock production regions have soils and topography that is not suitable for soil cultivation and annual crop production, so the geographic re-allocation of production is complex.

Conclusions

Care is needed to avoid large emissions from displaced crops, and more research is needed to predict the displacement and quantify the emissions. For this reason, we recommend that this measure is not taken forward as a practical GHG mitigation action within the current period of CAP policy (2014 to 2020).

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Maintain soil pH at suitable levels for crop/grass production

Introduction

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

Soil acidity (low pH) affects growth and yield of crops. Some fertilizers decrease soil pH, increasing the importance of this issue in modern agriculture. Soil acidity can be corrected (i.e. the pH can be raised) by soil application and incorporation of lime. Correction of an acid soil to optimum pH increases uptake of N and crop yield, influences soil microbial processes, and releases CO_2 as calcium carbonate dissolves.

Table recording results of the evaluation of soil pH maintenance

Assessment criteria	**Evaluation results**
Mitigation potential	There is large uncertainty in the balance between additional 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. This uncertainty increases when the indirect effects on emissions are calculated, especially through indirect land use change. We note that many farms already maintain soil pH well, especially for arable and root crops and high-value horticultural crops.
How effective is the action across the EU?	The need for the action varies with soil type, so there will be geographic variation in the need for soil pH adjustment. Where there is a need for the action, and the action is implemented, the effects will improve productivity across the EU.
Effect of variation in farmer implementation?	By definition, the aim of the action is to optimize pH. The detail of how this is achieved (e.g. type of lime applied, type of machinery used) will have little effect on the outcome, so long as the goal of optimum pH is achieved.
Compatibility with farming systems	Highly compatible and already practiced, but improvement is possible through encouragement of soil pH monitoring and maintenance on poor-performing farms.
Impact on farm income	Improved business performance is expected (positive, increase in wealth of rural communities).
Verifiable	Field sampling and testing: • The effectiveness of liming for soil pH correction can be checked by soil sample and analysis. Record Inspection: • Verifiable through farm records of soil pH assessment and correction (liming).
Co-benefits	Improved business performance through: • optimization of yields • efficient use of inputs (e.g. fertilizers).
Any adverse environmental impacts	Emission of CO_2 occurs as $CaCO_3$ dissolves and the carbonate is released as CO_2. There are also environmental impacts of activities to source and transport liming materials.

Social acceptance	Neutral – no major effects on social acceptability of production systems. Improved business performance is expected to improve social acceptability of farming activities through increase in wealth of rural communities.

Ecologic evaluation

This action is not addressed in the Ecologic report (Frelih-Larsen *et al.,* 2014).

Key points

Impact of soil pH maintenance on direct GHG emissions and removals

Emission of CO_2 occurs as $CaCO_3$ dissolves and the carbonate is released as CO_2 (Barton *et al.,* 2014). In grassland this emission has been shown to exceed the savings in GHG emissions (CO_2e) associated with more efficient use of N (Gibbons *et al.,* 2014). The timing of the emission from carbonate is uncertain, and probably differs from the usual carbon accounting assumption that all carbonate dissolves and is released as CO_2 within a year of application (Barton *et al.,* 2014).

There are also potential direct effects on N_2O emissions through effects on microbial processes, but the effects under differing climatic conditions and soil types are not clear. Furthermore, the long-term effects may differ from effects within an annual cycle, as microbial populations adapt to changed pH.

Research work in semi-arid environments has shown that liming of N fertilized soils decreased N_2O emissions and increased CH_4 uptake (Barton *et al.,* 2013).

Effects on quality of forage crop and therefore on enteric methane emissions?

We have not found literature on this subject.

Effectiveness (compared with current emissions) at a landscape scale

Effectiveness at a landscape scale of all the above potential mitigation mechanisms depends on the extent to which this action is already adopted/practiced on farms. Many farms already maintain soil pH well, especially for arable and root crops, and high-value horticultural crops.

Leakage (production displacement) Indirect effects on GHG emissions

The effect on GHG emissions depends upon the impacts on crop yields, which have an indirect impact on total emissions through land use changes in response to market pressures. This is very uncertain and therefore not usefully quantified. However, it would be possible to estimate the likely order of magnitude of this effect.

Conclusions

There is poor evidence to support soil pH maintenance as a GHG emissions mitigation action. There is large uncertainty about the balance between, on the one hand, emissions from lime application, and on the other hand, removals (e.g. additional removal of CH_4) and saved emissions (especially N_2O). The possibility of changes to GHG emissions through changes in land use (expected to be a decrease in LUC emissions as a consequence of increased production) add to the uncertainty. A recent review (Paraledo *et al.,* 2015) concluded that the impact of liming on C sequestration should be a priority for research due to continued uncertainty over the overall impacts of liming on soil C stocks. As a result of these considerations we do not recommend that this MA should be considered further.

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

Introduction

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

Readily decomposable C in organic manures has the potential to enhance denitrification of NO_3^- present in soil and emissions of N_2O. The potential is perhaps greatest when farmers apply manures and NO_3-containing fertilizers at the same time to meet the nutrient requirements of the next crop (Stevens and Laughlin, 2001).

Table recording results of the evaluation of a delay in applying mineral N to a crop that has already had slurry applied

Mitigation potential	By delaying the application of N-containing fertilizers, emissions of N_2O can be reduced. There are insufficient field data to quantify the effect.
How effective is the action across the EU?	This is likely to vary across the EU with the greater potential for abatement in regions with frequent rainfall in late spring and summer.
How sensitive is the action to farmer implementation?	This would be sensitive to farmer implementation as the interval between slurry and N fertilizer application would need to be strictly observed.
Compatibility with farming systems	This depends on the crop and time of year when slurry and N fertilizer are to be applied. The greatest risk of conflict is likely to be when fertilizer is to be applied to grass cut for silage. At these times farmers are keen to apply the N requirement as soon as possible after the cut grass is removed from the field in order to minimise the risk of grass yield being reduced.
Impact on farm income	
Verifiable	
Field sampling and testing	Not applicable.
Remote sensing	Not applicable.
Record Inspection	The time interval between slurry and N fertilizer application may be verified from farm records.
Other	
Co-benefits	None.
Any adverse environmental impacts	
Social acceptance	Not a mitigation action likely to attract attention.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) did not evaluate this option.

Key points

Stevens and Laughlin (2001) carried out 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. On average, applying CS at the same time as KNO_3 increased the flux of N_2O by 0.63% of the applied NO_3–N 104 hours after application. The maximum flux of N_2O was always observed in the first measurement period (5 to 7 hours) after CS application. All of the N_2O was formed by reduction from NO_3 apart from in August when 10% was formed by nitrification in the CS treatment.

We found no further results of work to evaluate the mitigation potential of this approach.

Leakage (production displacement)

This mitigation action is unlikely to lead to leakage.

Conclusion

There are not enough data reporting reductions in GHG emissions from adoption of the mitigation action to recommend this mitigation action be considered further within this project.

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Livestock disease management

Introduction

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

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. Over a period of time these will be seen to a greater or lesser extent on most (80 to 100%) UK dairy herds. 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.

In a study of the costs of maintaining the health of herds of dairy cows in France, Fourichon *et al.,* (2001) found the average cost €1.14 per 100 kg milk. Costs tended to increase with intensification. The variability of health control costs among the farms studied indicated there was potential to improve health management.

A recent UK study by Elliot *et al.,* (2014) did find some cost-effective approaches by improving cattle health. These were:

- Vaccination against calf pneumonia (-£172).
- Udder routine at milking to counter mastitis - including cleaning and post-milking dipping (-£158).
- Vaccination against Infectious Bovine Rhinotracheitis (IBR) (-£95).
- Colostrum management and hygiene to reduce incidence of Johne’s disease (-£82).
- Dry Cow Therapy for mastitis (-£51).
- Buying policy, test and cull to reduce incidence of Johne’s disease (-£51).
- Strategic treatment of Liver Fluke (-£40).
- Vaccination against Bovine Viral Diarrhoea (-£20).

The value in brackets is the net saving from reducing the incidence of the disease in £/tCO_2equivalent abated.

Table recording results of the evaluation of livestock disease management

Mitigation potential	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). 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.
How effective is the action across the EU?	The effectiveness is likely to vary considerably depending upon the current state of herd health.

How sensitive is the action to farmer implementation?	Likely to be sensitive as although any actions will be implemented by vets, the farmer will need to both identify that a health problem exists and also be willing to call on a vet.
Compatibility with farming systems	This is likely to be highly compatible with farming systems as reduced disease incidence should improve performance and returns.
Impact on farm income	Some proposed actions are already cost-effective. However, some are not.
Verifiable	Very difficult. An accurate assessment would require: • Reliable estimates of the reduction in GHG emissions (or emission intensity) from reducing disease incidence. • Reliable information on the current incidence and severity of a range of livestock diseases. • Reliable records of improvements in the disease status of livestock populations.
Field sampling and testing	Not appropriate.
Remote sensing	Not appropriate.
Record Inspection	Can be used to monitor if action taken.
Other	
Co-benefits	Reducing the emissions intensity of livestock production should lead to a range of co-benefits due to more efficient production.
Any adverse environmental impacts	Improving livestock health should not have any adverse impacts as increasing production without increasing either inputs or livestock numbers will reduce all emissions per tonne of product.
Social acceptance	This is likely to be good. Improvements to livestock health should also lead to improvements in livestock welfare which is an issue of considerable public concern in at least some EU MS.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) found that there is significant potential for mitigating emissions by improving animal health. They also considered that due to the productivity benefits that arise from improving animal health, much of this mitigation potential could be achieved at low or negative cost.

Key points

Factors influencing health control costs

Fourichon *et al.,* (2001) cite selection of animals for increased milk yield, greater milk solids and larger animals increased requirements for health care. Health costs were also greater for open than for closed farming systems. Farming systems that lessen contact between farm staff and the cattle, i.e. due to extensification or diversification, also lead to increased health costs. For example, costs were greater in mixed beef and dairy farms than in specialized dairy farms. There was no effect of herd size on health control costs.

Applicability

While the mitigation potential of reducing disease is starting to be recognised, only a small number of studies have attempted to quantify it within the EU (Frelih-Larsen *et al.,* 2014).

Timescale over which mitigation action becomes effective and duration

The timescale should be short, with the mitigation action maintained for as long as stock health remains satisfactory.

Leakage (production displacement)

Improvements to livestock health should lead to increases in production and production efficiency. These are likely to improve the competitiveness of EU livestock production. Hence improving livestock health within the EU would not be expected to lead to transfer of production elsewhere.

Conclusions

This mitigation action should be given further consideration as an option for GHG abatement that should be encouraged and promoted. In some cases it is likely to prove difficult to establish the abatement that can be achieved but it would be worthwhile to identify those diseases which lead to the greatest impairment of livestock performance and which of those are amenable to treatment. Verification of actions should be straightforward from veterinary records but estimating GHG abatement would need to be modelled and the validity of current models needs to be assessed. However, it is more appropriate for promotion to improve animal health and welfare motivations. The impacts on GHG emissions at the farm scale may be detectable using a Carbon Calculator tool and further consideration for adoption under the CAP could be through that MA.

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Use of sexed semen for breeding dairy replacements

Introduction

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

Dairy cows need to be pregnant 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 are surplus to requirements and 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.

Technology, such as semen sexing (which may be expensive now but could become more economical), would improve the beef quality of the calves from the dairy herd and should increase the proportion of the beef from the dairy herd (Webb *et al.,* 2014). 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). 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 recording results of the evaluation of use of sexed semen for breeding dairy replacements in ruminants

Mitigation potential	Appears to be quite small, perhaps only 1% (Webb *et al.,* 2014). There is little work on the topic.
How effective is the action across the EU?	Likely to be equally effective across all MS.
How sensitive is the action to farmer implementation?	Will not be sensitive as the action will be implemented by vets.
Compatibility with farming systems	Would be compatible with intensive dairy systems in which animal health is closely monitored.
Impact on farm income	Currently expensive.
Verifiable	
Field sampling and testing	Not appropriate.
Remote sensing	Not appropriate.

Record Inspection	Easily verified by reference to farm and veterinary records.
Other	
Co-benefits	Would reduce the number of calves sent for immediate slaughter. May also reduce the incidence of calving difficulty (heifer calves are lighter than male calves), and improve biosecurity by allowing farmers to increase herd size while maintaining a closed herd (Teagasc, 2014).
Any adverse environmental impacts	
Social acceptance	Probably acceptable, given the favourable welfare implications, but may be considered unnecessarily intrusive.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) did not evaluate this option.

Key points

Webb *et al.* (2014) concluded that sexing semen, even if 100% successful, only achieves a 1% decrease in GHG emissions from beef production. It is noted that there are, not necessarily good, implications for the breed type of the beef.

Applicability

Technology such as semen sexing, is expensive now but if costs come down this mitigation could become feasible. This would improve the beef quality of the calves from the dairy herd, but does not increase the proportion of the beef from the dairy herd.

Leakage (production displacement)

This mitigation action is unlikely to lead to leakage.

Conclusion

There is not enough data reporting reductions in GHG emissions from adoption of the mitigation action to recommend this mitigation action be considered further within this project. The primary motivation for a farmer to implement this action is likely to be of economic nature rather than introducing this measure for greenhouse has mitigation.

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Breeding lower methane emissions in ruminants

Introduction

This mitigation action is considered with respect to its potential for reducing emissions of CH_4. This mitigation action is envisaged as breeding distinct breeds of ruminants with reduced emissions of CH_4 per tonne of product.

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.

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. 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). 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 recording results of the evaluation of breeding lower methane emissions in ruminants

Mitigation potential	To be determined
How effective is the action across the EU?	Likely to depend upon the livestock currently in use.
How sensitive is the action to farmer implementation?	If more productive breeds can be developed which emit significantly less CH_4 than current, implementation should be independent of the farmer.
Compatibility with farming systems	Compatible. Breeding for improved production is well established.
Impact on farm income	Depends on the ratio of additional cost to additional input.
Verifiable	

Field sampling and testing	Not appropriate.
Remote sensing	Not appropriate.
Record Inspection	Can be done by presenting evidence of breed.
Other	
Co-benefits	
Any adverse environmental impacts	
Social acceptance	There may be some concerns that such breeding is changing the inherent characteristics of ruminants.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) did not evaluate this option.

Key points

Applicability

This action cannot be implemented on farms until a breeding programme has been carried out.

Leakage (production displacement)

Since the mitigation action is linked with improved productivity, and may therefore increase the competitiveness of the UK livestock industry, it does not appear to be a mitigation action likely to lead to leakage.

Conclusions

Selection to produce breeds of ruminants that emit less CH_4 has been initiated in at least one Member State (MS). Once breeds that emit less CH_4 become available, their adoption by farmers could be incorporated into CAP. However, it may be considered that promoting measures that can also increase productivity is not appropriate for CAP.

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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.

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Feed additives for ruminant diets

Introduction

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.

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.

Table recording results of the evaluation of using feed additives in ruminant diets

Mitigation potential	Depending upon the feed additive used, CH_4 emissions may be reduced by up to *c*. 20%.
How effective is the action across the EU?	Should be effective in all regions of the EU.
How sensitive is the action to farmer implementation?	Likely to be more sensitive on cattle and sheep farms where a greater proportion of feeds are made from forages grown on the farm.
Compatibility with farming systems	Variable and will depend upon the additive used. Likely to be compatible with most farming systems since the additives also increase production. However some additives will not be used by organic farmers.
Impact on farm income	Likely to boost net farm income.
Verifiable	Verification of emission reductions may be problematic until more robust data are available on the GHG mitigation associated with feed additives.
Field sampling and testing	Not appropriate.
Remote sensing	Not appropriate.
Record Inspection	The use of additives will be easy to verify from farm records.
Other	
Co-benefits	There will be increased production per animal which should reduce overall emission intensity leading to reductions in other emissions.
Any adverse environmental impacts	
Social acceptance	Will depend greatly on the feed additive used. Fat addition should not cause concern but the use of probiotics or hormones is likely to do so because of legal issues. The use of Ionophores are forbidden in the EU – see further detail in Ionophore section below.

Ecologic evaluation

The Frelih-Larsen *et al.,* (2014) study only considered fat supplementation. They concluded that support for direct costs (i.e. increased feeding costs) is not practical to implement.

Key points

Applicability

Some farmers with high productivity dairy and beef herds are already supplementing livestock diets with fat to boost the energy content of the diet, especially in the most productive periods of the year. However, even for those animals, the total fat content might be below 5 to 6% DM (Frelih-Larsen *et al.,* 2014). Pellerin *et al.,* (2013; cited in Frelih-Larsen *et al.,* 2014) suggested that in France 5% of dairy cows receive feed that is supplemented with fats.

Ionophores

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. 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).

Fat supplementation

According to Frelih-Larsen *et al.,* (2014) the persistence of the mitigation effect has not been adequately addressed yet: some studies do report long-term effects, but data are inconsistent.

Leakage (production displacement)

As feed additives improve animal performance, thereby increasing productivity, it is unlikely that adoption of the mitigation action will lead to leakage.

Conclusions

This topic covers a number of options. The adoption of some of these would be difficult. However, the topic should be further examined to determine which, if any, feed additives might be suitable for promotion under CAP. In subsequent work only fat supplementation is evaluated further.

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Optimized feeding strategies for livestock

Introduction

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

This mitigation action aims to optimise 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 as a safeguard against a loss of production arising from a protein deficit through inaccurate analysis and/or formulation of the diet. Surplus N is not utilised 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 to complement them (Moorby *et al.,* 2007).

Best practice is to apply multi-phase feeding to animals grouped according to their growth stage, sex, reproductive status, exercise level, etc. The feed conversion ratio and nitrogen (N) utilisation are optimized for each group.

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. 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.

Precision grazing offers improved targeting of the nutritional requirements of pasture-based ruminants. Both animal performance and grass yield and quality are monitored and animals are matched to the best suitable fields (Frelih-Larsen *et al.,* 2014). Precision feeding of ruminants receiving a high amount of grass silage includes monitoring the forage quality and adjusting the concentrate ratio. Potentially the protein content of forages can be reduced by increasing the maize or wheat silage content of the diet at the expense of grass products, though it has undesirable effects on land use change (Frelih-Larsen *et al.,* 2014). If ruminants are being fed large amounts of concentrates, the diet can be adjusted by changing the composition of the concentrates.

Table recording results of the evaluation of optimized feed strategies for livestock

Mitigation potential	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 MS and in regions where livestock are raised extensively.
How effective is the action across the EU?	The effectiveness will vary greatly among farms and regions depending upon the composition of diets currently being fed. Components needed to improve precision of feeding, e.g. synthetic essential amino acids (SEAAs) may not be readily available in all parts of the EU.
How sensitive is the action to farmer	For pig and poultry farmers there will be little sensitivity as a range of feeds appropriate to the animal's growth stages are already available from feed

implementation ?	manufacturers. For cattle and sheep farms the sensitivity will be greater as feeds are more likely to be mixed on farm.
Compatibility with farming systems	May not be compatible with all farming systems as information of animal performance may not be available.
Verifiable	
Field sampling and testing	Not appropriate.
Remote sensing	Not appropriate.
Record Inspection	The adoption of phase feeding will be easy to verify from feed records.
Other	
Co-benefits	The main benefits from optimized feeding practices will be in reduced NH_3 emissions and NO_3^- leaching.
Any adverse environmental impacts	
Social acceptance	Likely to be generally good. May also bring benefits in terms of job creation or security in providing advice on diet formulation. There may be concerns in grassland areas if grass-based forages are replaced by maize - or cereal-based feeds. The use of SEAAs is not permitted in organic farming systems.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) evaluated ‘precision feeding and multi-phase feeding for livestock’. The report concluded there was additional uptake potential mainly on medium-sized farms, in the ruminant sector and in improving current practice. This mitigation action can reduce pollution by reducing N inputs and excretion. However, the greatest proven emission reduction was of ammonia. The effects on direct N_2O emissions from manure were not considered conclusive. While savings can be achieved in terms of feed costs, the capital investment required is likely to be an important barrier, especially for middle-sized and smaller farms.

Key points

Factors influencing feed optimization

The impacts of reducing N excretion on direct emissions of N_2O and emissions of CH_4 during manure storage were reported by Frelih-Larsen *et al.,* (2014) to be inconclusive.

Applicability

Precision and multi-phase feeding can be implemented for all types of livestock, including poultry, pigs and cattle. A wide range of technologies is available both for collecting information about the animals’ requirements (e.g. by checking their yield or N excretion) and for precise feed formulation, including feed analysis and feed mixing.

The number of phases and the GHG mitigation potential depend on the type of the animals and should be adapted to local circumstances (Frelih-Larsen *et al.,* 2014). In Europe, nutritional recommendations are widely available, but the availability of feedstuff needed for precise feed formulation (e.g. SEAA) might vary among countries and might limit the applicability of the operation (Frelih-Larsen *et al.,* 2014).

Precision and multi-phase feeding are more applicable to pigs and poultry than to ruminants, partly because it is easier to control and change the nutrient content of concentrates than of forages, and partly because ruminants' nutrient (in particular protein) requirements can be predicted with less accuracy than those of monogastrics due to the biochemical processes in the rumen (Frelih-Larsen *et al.,* 2014). Poultry usually can be fed in three to five phases (six phases are used for broilers in the UK), while two to five phases are generally applied for pigs.

Precision and multi-phase feeding are mostly applicable to bigger farms due to economies of scale. The capital investment and personnel requirements make the action less affordable to small farms. For example, in Denmark for pig farms it is considered to be applicable above 1,300 pig places (JRC, 2013; cited in Frelih-Larsen *et al.,* 2014).

A reduced N content in the manure implies that more N fertilizer would be required in field application, giving rise to increased GHG emissions from N fertilizer (JRC, 2013; cited in Frelih-Larsen *et al.,* 2014). However, Pellerin *et al.,* (2013; cited in Frelih-Larsen *et al.,* 2014) suggests that there is little impact on the fertilizing value of manure.

Moran *et al.,* (2008) evaluated the cost-effectiveness of increasing concentrates and maize silage in the diets of dairy and beef cattle and reported the greater use of maize silage to be a cost effective option for dairy cattle.

Timescale over which mitigation action becomes effective and duration

The mitigation action will become effective as soon as improved diets or phase feeding are introduced.

Leakage (production displacement)

As improved feeding practices are implemented to at least maintain, if not increase productivity, it is unlikely that adoption of the mitigation action will lead to leakage.

Conclusions

This mitigation action is recommended for consideration for adoption into the CAP.

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.

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Anaerobic digestion (to reduce GHG emissions during manure storage)

Introduction

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

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.

As well as reducing GHG emissions, Massé *et al.,* (2011) reported the following benefits that may be derived from AD:

- Reducing the P surplus by precipitating up to 25% of it in batch or semi-batch operated bioreactors, and by precipitating and concentrating up to 70% of bioreactor effluent P in long term storage bottom sludge.
- AD digestates are better balanced to meet crop nutrient requirements than raw slurries, thereby reducing the need for supplementary fertilizer N and P.
- Reduction of the risk of water pollution associated with slurries (i.e., eutrophication) by removing 0.80–0.90 of soluble chemical oxygen demand.
- Some AD eliminate zoonotic pathogens and parasites in livestock manures.
- AD reduces odour emissions by 70 to 95%, allowing more frequent and better timing of manure land application.
- Both timing of application and improved nutrient balance have the potential to increase nutrient uptake by crops and minimize nutrient losses to the environment.
- Reduction in the viability of weed seeds during AD reduces the need for herbicides and makes bioreactor effluent more acceptable to organic farmers.

However, Massé *et al.,* (2011) cautioned that inadequate regulatory policies and incentives are obstacles to widespread implementation of AD in developed and developing countries. However, adoption of AD is an alternative which could substantially reduce the carbon and environmental footprint of housed livestock operations.

Soland *et al.,* (2013) reported acceptance of biogas plants by local residents in Switzerland is relatively high.

Table recording results of the evaluation of anaerobic digestion

Mitigation potential	The adoption of AD can reduce emissions of CH_4 from manure storage.
How effective is the action across the EU?	The action is likely to be more effective in warmer regions as the emission of CH_4 from stored manure increases with temperature.
How sensitive is the action to farmer implementation?	Farmer implementation of AD should not vary significantly. However, the management of stored manures is likely to vary considerably among farmers, hence there will be variation in unabated emissions.

Compatibility with farming systems	AD can be compatible with farming systems. The digestate can contain more available N and a more consistent content of available N than untreated manures. This increases the confidence in manure as a reliable source of N from crops. The main barriers to the uptake of AD on farms are the large capital cost and, for cattle farms, the lack of a consistent supply of manure feedstock throughout the year. The most promising approach to using livestock manures for biogas production is to build centralised AD plants that also use liquid food wastes as a substrate and utilise the energy on site in food processing.
Impact on farm income	Would provide an additional source of income from the CH_4 and/or electricity produced.
Verifiable	
Field sampling and testing	Not applicable
Remote sensing	May be possible to identify AD plants but not their impact on emissions during manure storage.
Record Inspection	The adoption of AD can be readily verified by recording digester output.
Other	Verification of the GHG emissions abated would need to be based on modelling of the emissions of manures that would otherwise have been untreated.
Co-benefits	There can be other environmental benefits such as better utilization of manure-N, reduced risk of P entering watercourses and overall reduced risk of water pollution. In particular, the use of centralised AD plants can enable a better distribution of livestock manures by diverting digestate from farms with surplus manure to farms with capacity to apply more manures. Battini *et al.,* (2014) reported that GHG emissions from dairy farming on the Po valley could be reduced by 24% if digestate is stored in an open tank but by 37% if digestate is stored in a closed tank. This would also reduce NH_3 emissions.
Any adverse environmental impacts	
Social acceptance	This is likely to be good. However, there may be objections to centralised AD plants as these will require transport of livestock manures to the AD plant and then transport of the digestate to farms for application to land.

Ecologic evaluation

This option was not evaluated by Frelih-Larsen *et al.,* (2014).

Key points

Factors influencing GHG reduction

More recent work by Rodhe *et al.,* (2014) indicates that GHG emissions during manure storage may be greater from digestate than from raw slurry during summer. No differences were reported for slurry stored over winter. Rodhe *et al.,* (2014) reported that the volatile fatty acid content of the digestate was ‘low’ while the CH_4 conversion factor (MCF) of the digestate was 2.2% in summer and 0.5% in winter. Both values are less than the typical 2.7% MCF reported for cattle slurry in Sweden. 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 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.).

Covering the digestate store significantly reduced CH_4 emissions. Storage under gas-tight covers and collection of any CH_4 generated was suggested as a means of reducing CH_4 emissions and increasing overall CH_4 production.

Applicability

Brown *et al.,* (2007), in a study of farms in Nova Scotia, concluded that without incentive schemes, on-farm biogas energy production was not economically feasible across the farm size ranges studied (200 to 800 sows; 50 to 500 dairy cows, except for 600 and 800 sow units). Among single policy schemes investigated, green energy credit policy schemes generated the greatest financial returns, compared with cost-share and low-interest loan schemes. Combinations of multiple policies that included cost-share and green energy credit incentive schemes generated the most improvement in financial feasibility of on-farm biogas energy production, for both pig and dairy farms.

The potential for reducing on-farm 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, the extent to which the technology may be taken up is uncertain. Tranter *et al.,* (2011) assessed potential uptake in England from a survey of 381 farmers. Around 40% of respondents indicated they might install AD on their farms. The possible adopters tended to have large farms and might utilise some of their land for feedstock production along with the manure from their livestock. Further, there are considerable perceived barriers to the widespread adoption of AD on farms in England. These include the capital costs of installing AD and doubts about the economic returns being adequate to repay the investment.

Mbzibain *et al.,* (2013), in a survey of 2000 farmers in England, found AD to be the form of renewable energy least commonly adopted by farmers.

Timescale over which mitigation action becomes effective and duration

The action would become effective as soon as stores containing undigested manure have been emptied.

Impacts on other emissions

Battini *et al.,* (2014) reported a worrying increase of *c*. 42% in ozone formation due to emissions of NOx from gas combustion. Storing digestate in closed stores will reduce emissions of NH_3 during storage.

Leakage (production displacement)

Since production will not be compromised, adoption of this mitigation action is unlikely to cause leakage.

However, since an AD plant is a long-term investment which can be optimised by having a continuous source of feedstock, it can create incentive to use material with higher energy content than manure or waste and lead to farmers growing crops such as grain maize to provide an additional, buffer, feedstock replacing other crops. This might lead to (considerable) leakage effect and has also negative effects on biodiversity etc.

Conclusions

The adoption of AD in only to reduce GHG emissions during manure storage will not be a cost-effective action. Anaerobic digestion should only be adopted if it produces renewable energy cost-effectively. However, an AD plant is a long-term investion and requires feedstock to run and thus it can create an incentive to use material with a greater energy content than livestock manures or biodegradable wastes (e.g. on-farm wastes of wastes from food processing) thereby motivating farmers to grow maize monoculture to provide a high-energy feedstock. This might lead to (considerable) leakage and negative effects on biodiversity.

We conclude that AD is beneficial as long as it is ensured that only livestock manures and wastes are used. If this restricition is included then this action could be adopted under CAP to ensure that digestate stores are covered so that CH_4 emissions are minimised, or the CH_4 is collected and added to the overall production, to ensure net CH_4 emissions during storage are reduced.

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Soil management plans

Introduction

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

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.

Table recording results of the evaluation of soil management plans

Assessment criteria	Evaluation results
Mitigation potential	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.
How effective is the action across the EU?	The action is effective across a wide range of soil types and farming systems, and so is effective across the EU.
How sensitive is the action to farmer implementation?	The validity of a soil management plan is reliant on the accuracy of data entered into the plan, frequency of monitoring implementation of recommended actions and recording outcomes and amendments from the plan to reflect actual performance on farm over the year. Therefore the action is highly sensitive to farmer implementation. For example recording if a field was identified as compacted and the details of any remedial actions taken.
Compatibility with farming systems	These management plans can be used on all farm systems.
Impact on farm income	There are associated costs with preparation of a management plan. Frelih-Larsen *et al.,* (2014) suggested costs of €100/farm/yr based on expert estimation for an erosion prevention plan, but did not indicate if this is establishment or an annual review. Expert judgement suggests that initial preparation can take 1 to 2 days of advisor time dependent on the size of the farm and 0.5 to 1 day for an annual review. Advisor day rates vary considerably across the EU. Cost savings can be achieved if the farmer is suitably skilled to complete their own soil management plan. There may also be capital and maintenance costs associated with the establishment of a mitigation option recommended and selected from the management plan. For example: subsoiling. The use of soil management plans can assist in identifying issues and management requirements, but also quantify frequency of mitigation actions and therefore the associated costs.
Verifiable	<u>Soil Management Plans</u> As for nutrient management plans, we recommend a detailed verification of the appropriate design of the plan. Soil erosion plans are a long commitment with a minimum duration of five years. Verification can include:

	• Visual soil assessments to assist in identifying soil types and soil structure issues, and to verify soil classification maps which can have a range of scales. • Use of penetrometers to assess compaction levels within fields. • Use of remote sensing or aerial photography to identify soil movement.
Field sampling and testing	
Remote sensing	
Record Inspection	The planning action is verifiable by record inspection.
Other	
Co-benefits	• Reduced nutrient loss to water and losses of air pollutants to the atmosphere. • Improved soil structure, macro and micro porosity. • Soil water retention and availability. • Improved potential for increased root mass and therefore yield potential. • Targeted mechanisation and potential for reduced machinery costs.
Any adverse environmental impacts	None identified.
Social acceptance	Anecdotal evidence indicates management plans can be seen as compliance tools e.g. for Nitrate Vulnerable Zones (NVZs) - not as business management tools to influence capital expenditure and management decisions. Requires additional investment in education and guidance to ensure uptake whether at a farm or advisor level.

Ecologic evaluation

Erosion control plans were reviewed in the Ecologic report, (Frelih-Larsen *et al*., 2014)

Benefits include:

Increased efficiency of soil erosion prevention in order to achieve:

- Reduced SOC loss
- Reduced GHG emissions (direct N_2O and CO_2 from fertilizer manufacture)
- Reduced energy use

The use of an erosion control plan can increase the efficiency of actions that contribute to:

- Reducing direct emissions from N fertilizers
- Reducing the CO_2e emissions from fertilizer manufacture
- Reduction in N leaching
- Reduction in the amount of N that needs to be applied to the following crop

In order to accomplish adaptation by the application of the control plan the following operation or combination of operations is/are proposed:

- Provision of payments for the development of soil erosion plan
- Provision of payments for the documentation of the implementation of the plan

Key points

Factors influencing GHG reduction

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.

Soil compaction alters the biological activity and decreases porosity creating anaerobic conditions which result in decomposing organic matter being released as CH_4 rather than CO_2. Identifying areas on farm where soil compaction is a risk and can be remediated is a key aspect of soil management plans.

Impact on direct GHG emissions and removals

No evidence was found for management plans to directly reduce GHG emissions. GHG abatement was found to be a result of implementation of actions and recommendations identified in a management plan.

Applicability

Soil management plans have been funded / subsidised in some EU countries under agri-environment measures. To implement this on a member state scale could have considerable cost implications. Further investigation is required to understand the impacts of this.

Indirect effects on GHG emissions (including leakage)

Leakage of GHG emissions through displacement of production is not likely to occur because use of soil management plans is not likely to decrease production.

Conclusions

It is recommended that soil management plans do not only include soil erosion by water and wind, but also consider the deterioration in soil physical, chemical and biological properties.

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Nutrient management plans

Introduction

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

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.

Leip *et al.,* (2011) also states that there is no consistent estimation for nitrogen surplus for countries in the European Union available which covers the three mentioned approaches.

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.

Table recording results of the evaluation of nutrient management plans

Assessment criteria	**Evaluation results**
Mitigation potential	The mitigation potential depends on the action(s) included in the plan, and the implementation of those actions. The adoption of nutrient management plans can lead to increased nutrient use efficiency and the reduced use of inorganic fertilizers, with consequent mitigation of GHG emissions. Mitigation potential will vary between seasons depending on differences in weather and crop performance. If using a soil surface nutrient budget, it can be difficult to assess mitigation of GHG emissions.
How effective is the action across the EU?	The action is effective across a wide range of soil types and farming systems, and so is effective across the EU.
How sensitive is the action to	The validity of a management plan is reliant on the accuracy of data entered into the plan, frequency of monitoring implementation of

farmer implementation?	recommended actions and recording outcomes and amendments from the plan to reflect actual performance on farm over the year. Therefore the action is highly sensitive to farmer implementation. Depending on the design of the nutrient budget, there may be sensitivity within the budget between planned actions and actual actions and events. For example the amount of fertilizer purchased by a farmer, may differ from the actual amount applied or the timing of the application, if management practices are adjusted to account for weather events.
Compatibility with farming systems	These management plans can be used on all farm systems. Nutrient management plans need to be standardised and robust in order to be used as a reportable measure. Variations in outputs of surplus/deficit can occur for example if soil data used in the nutrient budget programme differs from the soil information related to the farm, for instance a sandy soil is selected as the soil type instead of a clay loam as the interaction and uptake of nutrients will differ. Standardising the method for the use of a nutrient budget can reduce the likelihood of input errors which may occur with the end user.
Impact on farm income	There are associated costs with preparation of a management plan. Expert judgement suggests that initial preparation can take 1-2 days of advisor time dependent on the size of the farm and 0.5-1 day for an annual review. Advisor day rates vary considerably across the EU. Cost savings can be achieved if the farmer is suitably skilled to complete their own nutrient management plan. Significant costs savings may be achieved through reduced fertilizer costs but can vary among farm types. Mixed farming systems may offer the greatest saving due to the access to organic nutrient sources for use within arable rotations. There may also be capital and maintenance costs associated with the establishment of a mitigation option recommended and selected from the management plan. For example: arable reversion or the use of cover crops.
Verifiable	<u>Nutrient budgets</u> Verification of nutrient management plans can be a simple verification that the plan exists, or can be a more detailed verification of the appropriate design of the plan. We recommend the latter, and for this, the following data will need to be checked: • Input data over 3 or more years to account for weather and yield variations. • Require detailed and accurate datasets to increase accuracy of budgets and plans, such as soil analysis data. • Feed and livestock inputs and exports.
Field sampling and testing	
Remote sensing	
Record Inspection	The planning action is verifiable by record inspection.

Other	
Co-benefits	• Reduced nutrient loss to water and losses of air pollutants to the atmosphere. • Potential cost saving on imported nutrient sources. • Increased yield potentials due to identifying and rectifying the limiting nutrients, for example P and K applications are often avoided to save costs but this has the potential for negative impacts on production and the loss of other nutrients such as N. • High yield potentials due to optimizing soil pH.
Any adverse environmental impacts	None identified.
Social acceptance	Anecdotal evidence indicates management plans can be seen as compliance tools e.g. for Nitrate Vulnerable Zones (NVZs) - not as business management tools to influence capital expenditure and management decisions. Requires additional investment in education and guidance to ensure uptake whether at a farm or advisor level.

Ecologic evaluation

Nutrient management plans were not reviewed in the Ecologic report (Frelih-Larsen *et al.,* 2014).

Key points

Factors influencing GHG reduction

The use of nutrient 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 efficiency of nutrient applications and improved soil structure for rooting potential can increase biomass production, which will increase or maintain soil carbon levels.

The relationship between nutrient uptake for increased plant growth and soil nutrient cycles is complex and elements which influence GHG emissions cannot be considered in isolation. For example N uptake can be reduced by damaging levels of elements such as aluminium and manganese but also by the deficiency of calcium, magnesium and molybdenum (Gibbons *et al*., 2014). Identifying soil deficiencies / excesses of other nutrients through a nutrient plan may lead to increased NUE. Highlighting the flexibility and targeting potential that a nutrient management plan may provide.

Nitrogen surpluses are important because they influence the potential for nutrient loss to occur. Farms with greater surpluses are more likely to generate larger losses on average (Oborn *et al*., 2003).

Soil compaction alters the biological activity and decreases porosity creating anaerobic conditions which result in decomposing organic matter being released as CH_4 rather than CO_2. Identifying areas on farm where soil compaction is a risk and can be remediated is a key aspect of soil management plans.

Impact on direct GHG emissions and removals

No evidence was found for management plans to directly reduce GHG emissions. GHG abatement was found to be a result of implementation of actions and recommendations identified in a management plan.

Applicability

In the UK a farm gate budget e.g. PLANET is the most common tool for assessing the nutrient loads coming in and going out of the farm gate.

In any budget there are factors out of control of the farmer, for example rainfall patterns can affect the N balance from year to year potentially increasing the emission of N_2O if N is in excess. However, farmer can apply official N_2O emission factors as they are used in the national GHG emission inventories. These will provide a relatively robust measure of N_2O emissions. As the N_2O emissions are only a minor part of the overall N-budget of the farm (its importance for climate change is linked to the very high GWP) this is appropriate as the measure should not 'punish' a farmer for weather conditions that lead to higher N_2O emissions in one specific year as compared to long term average for the conditions at the farm. Overall, the total N input to soils is a good indicator for N_2O emissions and a reduction of the farm N-surplus a good indicator also for reductions of N_2O emissions.

Uptake of nutrient management decision support tools in the UK has been low by farmers. Of 49 farmers surveyed (Gibbons *et al.,* 2014) none had used the two government sponsored computer programs for nutrient planning (PLANET & MANNER).

Discussing the decision support tool Farmscoper, Gooday *et al*., (2014) found the perception was that Farmscoper was more likely to be used by advisors. However, Gibbons *et al*., (2014) found that of 49 farmers surveyed 25 used no external sources of advice.

Indirect effects on GHG emissions (including leakage)

The use of nutrient management plans is aimed at improving nutrient efficiency. This could have an indirect positive impact on GHG abatement through the reduction of inorganic fertilizers, saving emissions from the production of synthetic N as well as direct emissions of N_2O from N fertilizer.

Leakage of GHG emissions through displacement of production is not likely to occur because use of nutrient management plans is not likely to decrease production.

Conclusions

Farm nutrient plans:

In view of the high variability of N_2O emissions which are partly associated with parameters that are out of control of the farmers (weather) the use of established (constant but possibly stratified) N_2O emission factors is the most adequate way to quantify N_2O emissions. Therefore, the N surplus and the NUE can be regarded as **very** robust proxies for N-related climate relevant emissions. The less N input for equal production, the less nutrient losses to the environment occur and there is high probability that also N_2O emissions decrease accordingly.

Farm nutrient plans do not require large efforts for data collection (simplest version), in particular if combined with other measures (such as C auditing). A modular approach is possible, with increasing scope, for example including soil N measurements etc.

The Farm N-budget is a holistic measure with many co-benefits in other policy domains such as air and water pollution. They have a potential to increase the economic performance at the farm.

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Use of nitrification inhibitors

Introduction

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. 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.

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).

Table recording results of the evaluation of nitrification inhibitors

Mitigation potential	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.
How effective is the action across the EU?	There is likely to be some variation across the EU as the persistence of NIs in soil is reduced under warm and wet conditions.
How sensitive is the action to farmer implementation?	There should be little sensitivity to farmer implementation of NI-enhanced N fertilizers but good practice will need to be followed if NIs are added to livestock manures on the farm.
Compatibility with farming systems	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 could be spread at the same time as fertilizer / manure applications and all methods (except animal dosing) are easy to apply.
Impact on farm income	Due to the cost of NIs their use will reduce net farm income.
Verifiable	
Field sampling and testing	Not appropriate.
Remote sensing	Not applicable.
Record Inspection	The use of Inhibitors can be verified by purchase receipts although actual application may be less easy to verify.
Other	

Co-benefits	Can reduce NO_3 leaching losses by up to 35% (Moorby *et al.,* 2007) to 70% (Di and Cameron, 2002, 2005).
Social acceptance	Unknown. Most people are unaware of GHG emissions from agriculture and their mitigation and are therefore unlikely to have any view on the adoption of a GHG mitigation action. The use of another agrochemical spray may be viewed negatively, especially since DCD residues have been found in milk in New Zealand.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) did not evaluate this option.

Key points

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.

Influence of grazing by livestock

Ledgard *et al.,* (2007) demonstrated that ruminants supplemented with the NI DCD excreted the inhibitor unaltered in the urine. Further research is required to quantify the N_2O abatement potential of this approach, including a slow-release delivery mechanism, as this has great potential for the abatement of N_2O from urine in grazing systems.

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).

Influence of temperature on efficacy

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).

Impact on farm output

Beukes *et al.,* (2010b; cited in Doole, 2014) reported that although NI reduce N_2O emissions, they also reduce production, and therefore may consequently decrease farm profit. Additionally, 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%. Misselbrook *et al.,* (2014) reported there was no impact on crop yield or nitrogen uptake from the use of NIs.

Disadvantages

Schulte and Donnellan (2012) carried out a Marginal Abatement Cost Curve (MACC) analysis of GHG abatement options for Irish Agriculture and concluded that the use of NI was cost-prohibitive.

Adler *et al.,* (2013) also found NI were not a cost-effective option. The cost of NI application was cited as $200/ha. The authors do not state whether the currency unit is $US or $NZ, but since the work was carried out using a model of NZ Dairy farming we assume the latter. Hence the cost was *c*. €125 (€155 if the cost was given as $US).

Some studies have suggested potential increases in NH_3 volatilization and NH_4^+ leaching due to increased NH_4^+ accumulation in soil (Montes *et al.,* 2013).

Applicability

The greatest use of NIs in commercial farming has been in New Zealand where its application directly onto farm land has been one of the more promising ways of reducing NO_3^- leaching to waterways and GHG emissions from farming, particularly dairy farming, as well as promoting pasture growth.

However, as a result of finding DCD residues in milk, in January 2013 sales of DCD were voluntarily suspended and so was the use of DCD on farm land until further notice (http://www.mpi.govt.nz/news-resources/news/dcd-suspension-supported). This was because even very low levels of DCD residues found in milk may present a trade issue, even though there is no food safety concern associated with the use of DCD.

The problem is that there is no internationally set standard for DCD residues in food. This is because DCD has not been considered to have any impact on food safety. Because no standard exists, the detectable presence of DCD residues in milk could be unacceptable to consumers and international markets, even in the small amounts found in recent testing as, in some countries, there is a zero tolerance to detected residues outside agreed standards.

However, the use of NIs on tillage crops may be less problematic than the use on grassland. In addition, there does appear to be an EU standard for DCD residues in food (Misselbrook, pers. comm.). In addition, the presence of NI residues in NZ milk was a result of NIs being supplied directly to cattle, not as a result of the cattle eating forage to which NIs were applied. In this evaluation we are only considering the use of NIs included with N fertilizer products and hence the risk of food contamination with residues is negligible.

Leakage (production displacement)

Since there is some evidence that NI may reduce production, the adoption of NI poses some risk of leakage. However, reported decreases in production are small and hence the risk of leakage will also be small.

Conclusion

The use of NI with N applications, both mineral and organic has been demonstrated to be an effective means of reducing N_2O emissions. Most studies indicate that due to the considerable costs of NIs farmers are unlikely to adopt them. Hence this action could be appropriate for support under the CAP to increase the efficiency with which fertilizer- and manure-N are used and to reduce emissions of N_2O. Further evaluation will need to take account of the consequences of using NIs, in particular DCDs, on food safety.

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Improved nitrogen efficiency

Introduction

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. Elsewhere in this document we have evaluated candidate mitigation actions which may also be considered to improve N efficiency. Those actions are listed below together with the reasons for considering them separately:

Improving grassland management to increase carbon sequestration. This action includes the possibility of increasing N inputs in order to increase primary production and also considers grazing intensity and the choice of grass species.

Nutrient management plans. This action relates to those farmers who would benefit from the adoption of an overall nutrient management plan including improved use of other nutrients such as P and sulphur in order to improve N use efficiency rather than focus on one or two aspects of N management as discussed here.

Optimized feeding strategies for livestock. This action relates to the preparation of livestock diets.

Delay applying mineral N to a crop that has already had slurry applied. This action does not involve reducing the total amount of N to be applied to a crop, it relates to a specific management action to reduce the potential for denitrification of applied nitrate-N.

Use of nitrification inhibitors. Although this action can increase the efficiency with which applied N is used, it requires the use of an additional input and is directed toward abating an emission rather than to make more efficient use of existing resources.

Bio N fixation in rotations and in grass mixes. This proposed action aims to reduce total inputs of fertilizer-N by introducing additional (leguminous) species to the rotation, rather than taking better account of the contribution of any existing legumes.

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. Moorby *et al.,* (2007), in their review of then *current* GHG mitigation actions, evaluated the following approaches to increase N efficiency on farms:

- Do not exceed the economic optimum N fertilizer requirement.
- Make full allowance for manure N supply.
- Spread manure at appropriate times.
- Increase livestock nutrient use efficiency.

Actions such as carbon accounting and nutrient planning are discussed as separate MAs.

Do not exceed crop N requirements

This action reduces emissions of N_2O by ensuring that no more fertilizer-N is applied than is required by the crop for optimum yield. Requirements to comply with N fertilizer recommendation systems have been adopted in NVZ Action Plans. Furthermore, the large increase in the price of N fertilizer following the increase in oil prices in 2008 will have incentivised farmers to reduce N fertilizer use by ensuring no more is applied than needed for optimum yield. Although there have been subsequent decreases in price this will not axiomatically lead to a return to ‘insurance’ applications of N in excess of crop requirements.

Make full allowance for manure N supply

By making full allowance for the N applied in manures and reducing mineral fertilizer N inputs accordingly, total N inputs can be reduced which will reduce emissions of N_2O. This may be achieved by using a recognised fertilizer recommendation system and other guidance. It also helps to keep records of mineral fertilizer and organic manure inputs to individual fields.

Spread manure at appropriate times

This mitigation action has been incorporated into NVZ Action Plans by MS via the need to introduce closed periods for fertilizer and manure application over the winter period. By reducing the risk of available-N in manures being lost by leaching over winter more manure-N is available for crop uptake, reducing the need for fertilizer-N (Webb *et al.,* 2011)

Increase livestock nutrient use efficiency

This action was considered by Moorby *et al.,* (2007) with respect to improving N use efficiency in livestock diets and has been evaluated in the study as mitigation action 14, optimized feeding strategies.

Future actions evaluated by Moorby *et al.,* (2007) to reduce GHG emissions by increasing N efficiency were:

- Improved mineral fertilizer N timing strategies.
- Use plants with improved nitrogen use efficiency.

Below we briefly summarise individual aspects of increasing N efficiency.

Do not exceed crop N requirements

Most MS produce fertilizer recommendation systems which include recommendations for fertilizer-N applications to obtain optimum yield. Optimum in this context is the economic optimum where the value of any additional crop yield produced by above-optimum N fertilizer application will be less than that of the cost of the additional fertilizer. Numerous studies have reported that as N fertilizer applications are increased above the economic optimum so losses of N, in particular as NO_3^-, increase disproportionately, hence ensuring this optimum is not exceeded is a cost-effective means of reducing all N emissions. It is important to remember that applications of N fertilizer at less than the economic optimum amount will reduce crop yield and therefore financial returns to the farm and may also increase GHG emissions per tonne of product.

Make full allowance for manure N supply

Webb *et al*., (2011) recently reviewed means of improving manure-N efficiency throughout the EU. As well as making sure that reported estimates of the availability of manure-N to subsequent crops be fully taken into account it was also recommended that longer-term release of manure-N from litter-based manures should be considered when determining crop requirements of fertilizer-N. The use of reduced-ammonia emissions manure application techniques can increase the amount of manure-N available for crop uptake and thereby reduce the need for fertilizer-N. However, whether the use of these reduced-emission techniques will be cost effective will depend on factors such as the current price of fertilizer-N and the additional costs imposed by the use of reduced-emission spreading techniques.

Spread manure at appropriate times

Webb *et al*., (2011) also reported the importance of complying with closed periods for manure application. By spreading manures in the late winter and early spring not only is the risk of NO_3^- leaching greatly reduced but the N conserved by reducing leaching remains in the soil available for crop uptake.

Improved mineral fertilizer N timing strategies

This action was proposed by Moorby *et al.,* (2007) as the development and application of mineral N fertilizer application timing approaches to avoid large amounts of NO_3^- in the soil under wet and warm conditions. A substantial proportion of N_2O emissions arise from the nitrification and denitrification of mineral N fertilizer applications to soils that are made periodically during the growing period. Moorby *et al.,* (2007) considered that such emissions are highly 'event driven' in that high emissions (greater than 0.5 kg N/ha/d) typically occur only during a small number of days when applications concur with wet and warm conditions in the soil. If such events could be avoided then large reductions in emissions could be achieved. Avoidance might be possible using soil tests and/or weather forecasts.

Use plants with improved nitrogen use efficiency

Moorby *et al.,* (2007) considered this action as the use of genetic variability in crops to breed for plants that require less N fertilizer than current cultivars.

Table recording results of the evaluation of use of crop cultivars with improved nitrogen use efficiency

Mitigation potential	Appears to be quite small within some EU regions. Some of the specific actions are already being implemented via NVZ Action Plans and there may be little potential for further implementation where these Action Plans have been fully implemented. Other actions require the development of very reliable weather forecasts or crop cultivars that reach optimum yield with less N fertilizer than current varieties.
How effective is the action across the EU?	This is likely to vary greatly across the EU depending upon the extent to which farmer practice has already been modified to comply with NVZ rules.
How sensitive is the action to farmer implementation?	Some sensitivity.
Compatibility with farming systems	The actions are broadly compatible with farming systems in that they aim to reduce usage of a costly input (N fertilizer) without reducing production. However, they may increase workload which would pose problems on farms where there is no slack in the system.
Impact on farm income	
Verifiable	
Field sampling and testing	Not applicable.
Remote sensing	Not applicable.
Record Inspection	Adoption of the actions would be verified by reference to farm records. In addition farm records should also indicate a reduction in overall N fertilizer use.
Other	Modelling may be required to verify reductions in N_2O emissions.
Co-benefits	Using N more efficiently would reduce NO_3 leaching.
Any adverse environmental impacts	

Social acceptance	Probably acceptable, given the overall effect is to reduce inputs.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) evaluated the option of improving N efficiency by providing payments when N-surpluses are reduced below a defined threshold. Yield decline needs to be prevented in order to avoid indirect land use changes which would decrease the emission reduction potential. For this reason we only consider actions unlikely to reduce yields.

Key points

Improved mineral fertilizer N timing strategies

Underpinning knowledge and predictive forecasting approaches to the timing of mineral fertilizer N applications to minimise N_2O losses is lacking (Moorby *et al.,* 2007).

Do not exceed crop N requirements

Moorby *et al.,* (2007) reported that fertilizer recommendation systems can be used in all farming systems, but are particularly effective in intensive grassland, arable and horticultural systems. The method would have less impact in extensive grassland systems, as according to fertilizer practice surveys, most extensive grasslands receive less N than is recommended.

Make full allowance for manure N supply

Moorby *et al.,* (2007) considered that the method could be easily implemented via advice, education and guidance. Particular guidance is required with soil and manure sampling, on-farm analysis of manure, and interpretation of results.

Spread manure at appropriate times

This method is largely limited to those farms using slurry or poultry manure (Moorby *et al.,* 2007) as litter-based farmyard manures have small concentrations of N that is readily available for crop uptake and, in consequence, time of application makes little difference to the amount of manure-N available for crop uptake (Webb *et al.,* 2011). This method will only be applicable on farms that have sufficient storage capacity to allow a choice of when to apply slurry. Even where storage is adequate for normal conditions, exceptional weather or poor planning can create a situation where stores are full during a high-risk period so that land spreading is the only option (Moorby *et al.,* 2007).

Improved mineral fertilizer N timing strategies

The method depends on development of farmer friendly, site-specific tests or forecasts. Should such tests and forecasts be developed successfully then potentially the action could be applied in all circumstances. The action would probably be easy to apply, but would have important consequences for the farmers' day to day management and potentially on the periodicity of production during the growing season (Moorby *et al.,* 2007).

Use plants with improved nitrogen use efficiency

Moorby *et al.,* (2007) considered this action as the use of genetic variability in crops to breed for plants that require less N fertilizer than current cultivars. Can be applied in principle to all sectors of grassland and crop production agriculture.

Leakage (production displacement)

This mitigation action is unlikely to lead to leakage as the action is intended to maintain crop yields.

Conclusion

Frelih-Larsen *et al.,* (2014) considered that this action focuses on improving N efficiency by *optimizing* the amount of N fertilizer applied and factors that are influencing it *while at the same time maintaining yield level*. Such practice has long been advocated and subsequently required in NVZs. The existing actions to improve N efficiency are all actions currently implemented by MS in their Action Plans to reduce nitrate leaching. In consequence the potential for further abatement will vary considerably across the EU. In some regions, where NVZ Action Plans have been implemented and there is a large degree of compliance there may be little scope for further improvement. But in regions outside NVZs, or where Action Plans have not been fully implemented, incorporation into the CAP may be an effective means of further promoting the more efficient use of fertilizer-N.

The future actions proposed by Moorby *et al.,* (2007) depend upon the development of accurate and reliable weather forecasts and on the successful breeding of cultivars that can utilise N more efficiently. In view of the need for such advances before these specific action can be implemented we do not think it appropriate to consider them further.

The use of a nutrient plan, providing it covers the approaches listed here, is a useful tool to achieve improved N efficiency.

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Biological N fixation in rotations and in grass mixes

Introduction

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

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/yr 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).

There are two main categories of legumes: grain legumes, which include field beans, peas, and soya; and forage legumes, which include clover and alfalfa. Although these crops differ significantly in their role within farming systems and geographical distribution, their contribution to N inputs into agricultural systems is important.

Forage legumes form a major source of protein for ruminants (Luscher *et al.,* 2014; cited in Frelih-Larsen *et al.,* 2014). The use of legume-based forage systems predates the use of N fertilizers to produce forage crops, and is still practiced extensively in organic rotations. Due to increasing costs of fertilizer N, there is some evidence to suggest that such rotations are becoming more widespread in conventional farming (Frelih-Larsen *et al.,* 2014). Given the fluctuations in the price of N fertilizer, an N fertilizer tax that is used as premium payment for ecosystem services could be a means to stabilize the cost of N fertilizer and encourage the maintenance of means to optimize its use.

Grain legume production in Europe has declined significantly in recent decades, with the area under production of field beans being now only around 10% of levels in the early 1960s (FAO 2012; cited in Frelih-Larsen *et al.,* 2014). Most grain legumes consumed in Europe are used as livestock feeds. Despite the decrease in European production of grain legumes, consumption has increased through imports of soya. There is a perception amongst farmers that grain legume production is less profitable than the production of cereals. According to Frelih-Larsen *et al.,* (2014) in some regions of Europe, current market conditions make it profitable to produce grain legume crops if the full range of benefits is taken into account. In the UK gross margins from field beans can be comparable to those from winter barley and spring wheat (Nix, 2013).

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.

Including clover in grassland was considered to potentially reduce GHG emissions by 15 to 32% by Feliciano *et al.,* (2013) in Scotland.

Table recording results of the evaluation of biological N fixation in rotations and in grass mixes

Mitigation potential	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%.

How effective is the action across the EU?	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.
How sensitive is the action to farmer implementation?	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.
Compatibility with farming systems	This depends on the availability of markets for grain legumes in arable rotations and on successful introduction to grass swards so that the N fertilizer requirements are met and grass yields sustained.
Impact on farm income	
Verifiable	
Field sampling and testing	Not applicable.
Remote sensing	May be verified by means of satellite inspection.
Record Inspection	May be verified from farm records. In addition to checking the area of legumes planted, N fertilizer use can also be assessed to ensure that the potential benefit of increased legume use via reduced N fertilizer inputs is being implemented.
Other	
Co-benefits	In arable rotations, this mitigation action can offer opportunities to reduce the incidence of pests, weeds and diseases and may also increase biodiversity.
Any adverse environmental impacts	
Social acceptance	Likely to be seen as a favourable option by the public due to an increase in the variety of crops grown in arable areas.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) considered that the hectare premium (such as existed until recently in the CAP for peas, field beans and sweet lupins) appears to be the most effective in increasing the area under grain legumes. The action was considered to lead to a small increase in farmers' incomes (although achieved by arable farmers at the expense of livestock farms).

For forage legumes, an area-based payment was proposed, where the forage is cultivated for a minimum of one year as a part of an arable rotation or long term grassland. Payments would be conditional on maintaining at least 25% of the grass/legume mixture as a legume, and on using N application rates that are less than those for grass-only forages.

Key points

While 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, there is a perception that grass/clover swards require greater management than all-grass ones.

Legumes are more likely to suffer from sulphur (S) deficiency than grasses and in consequence can be out-competed by grass on sulphur-deficient soils (Tallec *et al.,* 2008). Emissions of sulphur dioxide (SO_2), and subsequent S deposition to grassland, are forecast to decrease further over the next 10 years (Webb *et al*., submitted) making S deficiency more likely in future. Supplementary fertilization with S is likely to be needed to ensure the success of any initiatives to encourage sowing clover in grassland.

While the introduction of grain legumes has benefits for arable farming, with respect to improved pest control and reduced N fertilizer use, there can be disadvantages. The late harvest of field beans and lupins will prevent early sowing of subsequent winter cereal crops and thereby reduce yields of the following cereals.

Leakage (production displacement)

This mitigation action could lead to leakage if increases in the area of grain legumes reduces overall farm production.

Conclusion

This mitigation action has potential and should be considered further within this project.

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Carbon auditing tools

Introduction

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

Carbon auditing tools provide a way of finding out where the largest carbon emissions arise. This then gives a breakdown of carbon sources and indicates emission hotspots which can be targeted for reduction. 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.

Carrying out a farm carbon audit is useful for farmers to (Frelih-Larsen *et al.,* 2014):

- Identify GHG emissions on farm and benchmark against other similar farm enterprises in order to identify cost savings, e.g. through improved use of inputs and energy efficiency.
- Investigate the impact of changing farm practices by running scenarios to see the effect the changes have on the overall GHG emissions of the farm.

Table recording results of the evaluation of carbon auditing tools

Assessment criteria	**Evaluation results**
Mitigation potential	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)’.
How effective is the action across the EU?	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.
How sensitive is the action to farmer implementation?	Likely to be very sensitive depending on the extent to which the farmer follows the recommendations. However, proper auditing will enable the payment to be related to farmer’s implementation.
Compatibility with farming systems	It was stated in Perez-Minana *et al.,* (2012) that ‘feedback on the tool from the farming community has so far been very positive’. It was also stated that the monetary value of emissions reductions should be stressed to incentivise farmers to take up emission reduction measures. This will also provide farmers with assistance in deciding how best to manage their emissions (Perez-Minana *et al.,* 2012). Depending on the rotation, a new audit may have to be carried out for each change to the farming system. The impact of cropping system on carbon

	footprint is discussed further in Gan *et al.,* (2011). Farming styles will also have an impact on agricultural GHG emissions (Feliciano *et al.,* 2014).
Impact on farm income	Uncertain. Will depend upon the cost of using the calculator and the current GHG emissions.
Verifiable	Perez-Minana *et al.,* (2012) stated that 'A pervading theme in all the solutions reviewed is the need to handle the uncertainty associated to this type of calculation'. Nevertheless, the outcome of this MA may be considered less uncertain than some of the other MAs as this will be based on standard and officially recognised methods. Some carbon auditing tools may also only look at CO_2 emissions, whereas others may include other GHGs (Kim and Neff, 2009). This can cause difficulties in making comparisons. 'Comparison between farms requires a standard measure to be applied to all farms and carbon calculators need to record crop yield and quality data at the very minimum to present GHG emissions per unit of output' (Franks and Hadingham, 2012). There will also be differences due to natural variation in environmental conditions and farm management practices (Jones *et al.,* 2014). This will also apply to many of the other measures. Kim and Neff (2009) raised the point that peer-reviews of carbon auditing tools are difficult and state that 'results cannot be held to a standard of accuracy and credibility'. This issue can be addressed by harmonizing the tools in order for them to deliver comparable results. The approach will need to be modular to cover different agricultural sectors.
Field sampling and testing	Not appropriate.
Remote sensing	Not appropriate.
Record Inspection	Would be able to inspect the carbon calculator output.
Other	
Co-benefits	Frelih-Larsen *et al.,* (2014) point out that reducing emissions may reduce costs and increase resource efficiency, thereby benefitting the wider business. Evidence of reducing emissions can also be used on product labelling; this may be a further incentive for farmers. Frelih-Larsen *et al.,* (2014) also stated that 'An assessment at farm level always results in a better knowledge of the farm and many advantages therefore arise through farm level assessments'. 'Economic improvements (money saving, better knowledge for future investments, added value for the product, etc.) as well as social benefits (improved effectiveness for certain tasks, optimization of time, etc.) are frequent when supporting farmers in this kind of process' (Frelih-Larsen *et al.,* 2014). - C tools could be used for C-footprinting and as a basis for C-labelling which might be economically interesting for farmers - C tools can harvest reduction in emission intensities which results from changes in farm practices that are 'unspecific' thus giving the

	farmer the incentive to manage resources carefully. There is a clear cross-benefit with resource efficiency targets, as the recycling and reuse of biomass at the farm will lead to a reduction of the C emissions - C tools can be designed in order to also encompass upstream emissions, thus incentivising the farmer to use low C-footprint feed etc. It can therefore play a role in transforming EU agricultural systems toward more sustainability
Any adverse environmental impacts	There are unlikely to be any major adverse environmental impacts unless a tool is used which does not alert the user to possible unintended consequences for other ecosystem services from GHG reduction.
Social acceptance	Farm level reporting of greenhouse gas (GHG) emissions is not required in Europe at present. However, many voluntary initiatives exist with the aim of evaluating GHG emissions from agricultural activities (Frelih-Larsen *et al.,* 2014). Financial support is required for a carbon audit (Frelih-Larsen *et al.,* 2014). A carbon footprint can provide a report which is easy for the farmer to interpret without having to understand the underlying science.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) evaluated financial support for a carbon audit carried out at the farm level over a cultivation period (defined as 'one crop season or year') by a 'certified' external adviser. The carbon audit would include an action plan in addition to the results showing the main sources of GHG emissions from the farm.

Frelih-Larsen *et al.,* (2014) suggested two possibilities for national authorities to support the use of carbon audits:

- In case of the absence of a local carbon audit tool, they should specify the software to be used which will help to create GHG references at farm level for different farming systems.
- In case of the existence of local carbon audit tool, they should (1) determine a list of data, stating which are mandatory or not or (2) determine a list of approved tools whose accuracy is judged to be sufficient enough to suggest an action plan at farm level.

Key points

Applicability

Kaetsch and Osterburg (2015) compared eleven GHG calculators from different countries. The function of all of the calculators was to determine GHG emissions or carbon footprints in order to target areas for emissions reductions. Some tools had additional benefits around improving agricultural advisory services and general awareness raising. Current tools may have large differences: Colomb *et al.,* (2012; cited in Frelih-Larsen *et al.,* 2014) state that 'There are a number of carbon auditing tools available for agriculture and forestry, all these calculators providing results in tCO_2e, but differing in system boundaries and parameters for calculations which significantly influence the final results'. There are also constraints which may result in low uptake: such as uncertainty over quantification of emissions, large time requirements, a lack of data quality, and a lack of incentives to use the tools (Kaetsch and Osterburg, 2015). However, their ability to measure where the greatest emissions are is a useful progression in terms of agricultural tools. Kaetsch and Osterburg (2015) determined that all the tools assessed were relatively easy to access and whilst some were more complex than others, the majority were user friendly. Long term developments are also in the pipeline for most of the calculators assessed; thus the usability and accuracy is likely to improve in the future (Kaetsch and Osterburg 2015). Kaetsch and Osterburg summarise by stating that 'Although carbon calculators are potentially powerful tools, their usage is still constricted and in most cases their relevance for decision making in the farm sector and in climate policies is limited'.

The messages given alongside a carbon calculator are imperative: 'even the most accurate and comprehensive calculator has little value unless it reaches a willing and able audience with a clear message' (Kim and Neff, 2009).

However, understanding the potential limitations of carbon calculating tools will enable the development of an agreed approach using consistent definitions of systems and agreed calculation procedures.

Disadvantages

'Carbon footprints of a sample of farms together with an analysis of the Kyoto Protocol show the difficulties encountered at each step… One consequence is that farmers may adopt mitigation activities that reduce their farm's, the UK agriculture sector's and the UK's emissions whilst inadvertently increasing global emissions: a trivial solution because it fails to address GHG emissions as a global problem.' (Franks and Hadingham, 2012). However, if the tool also calculates productivity, leakage avoidance can be built into the tool.

Franks and Hadingham (2012) also comment on the fact that carbon calculators should record 'individual farm financial data to estimate MACC [marginal abatement cost curves] for individual farms'. This would both produce interesting data, and would perhaps increase acceptance by farmers.

Barriers to uptake

The following bullet points are cited in Frelih-Larsen *et al.,* (2014):

- High number of data required for the carbon audit, variability of farm records across EU
- Economic barriers (absence of national investment subsidies program etc.) and technical barriers (insufficient technical advice).
- Farmers would be willing to do a carbon audit only if they had financial incentives
- Farmers seemed more ready to address practices that produced carbon dioxide emissions, particularly the use of energy and fuel on the farm
- Key risk/ uncertainty → Differences in methodologies and perimeters for calculations significantly influence the final results from carbon calculators for the agricultural sector.

It is however noted that farmers do pay for the use of footprinting tools such as the 'Cool Farm Tool' and therefore farmers may have their own motivations for carbon auditing.

Timescale over which measure becomes effective and duration

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".

Conclusions

Carbon tools are a relatively novel instrument and there are still large differences in existing calculators limiting the comparability and effectiveness of current data. Therefore, the suggestion of using Carbon Tools requires the development of clearly defined methodological guidelines. Work in other areas (greenhouse gas inventories, environmental footprinting) already provided a wealth of information on which this can build.

Modular system and national/regional extensions to reflect specific circumstances and mitigation options are possible.

Carbon tools clearly have considerable co-benefits as they provide a quantitative measure of the GHG emission intensity at farm level and address emissions from a holistic perspective.

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Improved on-farm energy efficiency

Introduction

This mitigation action is considered with respect to its potential for reducing emissions of CO_2.

Zero tillage (ZT) reduced energy use in arable rotations in Italy by 11% (Alluvione *et al.,* 2011). But those workers cautioned that if yields are reduced, which can be a consequence of ZT, the energy requirement per tonne of crop may not be reduced.

Nguyen *et al.,* (2010) concluded that pig farming in NW Europe could reduce fossil energy use by up to 61%, although most of this reduction (87%) was achieved by using manure to generate energy. No specific energy efficiency mitigation actions were evaluated.

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*. 1150×10^3 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.

Table recording results of the evaluation of increased energy efficiency

Mitigation potential	Estimates derived from a MACC curve indicate that emissions from on-farm energy use could be reduced by *c*. 25% by improving energy efficiency. The GHG emissions from the production of new machinery should also be taken into account.
How effective is the action across the EU?	This is likely to vary according to the equipment currently in use and hence will vary among farms within regions as well as among regions with less potential for the farms and regions with more modern, energy-efficient machines.
How sensitive is the action to farmer implementation?	This is likely to be very sensitive to farmer implementation as some farmers will assume the use of new machinery will automatically increase energy efficiency whereas others will realise they also need to apply best practice in the use of the equipment.
Compatibility with farming systems	The main constraint is the capital cost of new equipment.
Impact on farm income	Would reduce running costs.

Verifiable	
Field sampling and testing	Not applicable.
Remote sensing	Not applicable.
Record Inspection	Verification can be by monitoring on farm fuel use.
Other	
Co-benefits	Improved energy efficiency will reduce running costs.
Any adverse environmental impacts	
Social acceptance	Improved on farm energy efficiency is not likely to be noticed by the wider community.

Ecologic evaluation

Frelih-Larsen *et al.,* (2014) reported that improving the fuel efficiency of mobile machinery is one of the most effective ways of reducing energy-related emissions. This includes machinery used for irrigation. Frelih-Larsen *et al.,* (2014) reported that on citrus farms, irrigation accounted for from 32% of total energy (surface irrigation), to 55% of energy use (drip irrigation), and that the emissions arising from this energy use could be significantly reduced with a payback period of “a few years”. The report states that many farmers have expressed an interest in improving their fuel efficiency but lack the knowledge required to do so. In order to meet this need, the following operations were proposed:

- Provision of training in methods to reduce fuel consumption.
- Grants to (partly) cover the costs of purchasing equipment to monitor fuel consumption.
- Advisory support to develop a fuel use action plan, including provision of training in techniques to improve fuel efficiency such as eco-driving and tractor maintenance.

The report concluded that if barriers to uptake and rebound effects can be managed, this operation could lead to small but significant reductions in on-farm emissions and cost savings.

Key points

Variability of non-renewable energy (NRE) use

On beef farms the main driver of NRE consumption was fuel use (Veysset *et al.,* 2014). Fuel use per kg live weight (LW) tends to increase with farm size but is less on specialized beef farms. Veysset *et al.,* (2014) concluded that farms emitting the greatest GHG emissions (per kg LW) used 37% more NRE than those emitting the least GHGs. The authors considered their findings and argue against the idea that size and diversification bring economic and environmental economies of scale and scope in suckler-beef production systems.

Applicability

The barriers to uptake of potentially cost-effective mitigation actions most frequently identified by the UK MACC were:

- The value of the approach is not well appreciated or understood.
- Operators often think that the current equipment is working close to optimum performance. The use of a suitably calibrated carbon calculator could be used to give accurate indications of machinery performance.

- Upgrades are only considered when major refurbishments take place (which may only happen every 10 to 25 years).
- High capital costs. Even when mitigation actions can be demonstrated to be cost-effective in the long term the current lack of profitability within most agricultural sectors is a barrier to investment.
- For tractors and implements, expediency and the need to get a task completed means that the detailed set up and matching requirements are not properly considered.

Timescale over which mitigation action becomes effective and duration

Reductions in GHG emissions from agriculture can begin immediately when more efficient machinery or improved working practices are introduced. However, until the additional emissions created by the manufacture of new equipment are equalled there will be no net decrease in GHG emissions.

Leakage (production displacement)

Since the mitigation action is expected to reduce costs, and hence improve productivity, there should be no risk of leakage.

Conclusions

There is potential to reduce GHG emissions from farming by improving energy efficiency. A barrier to doing so is the high capital cost. Thus if financial incentives can be offered via CAP then farmers may be willing to install more efficient equipment. However, such a financial incentive to buy new equipment could lead to a perverse incentive to replace machinery that is performing well thereby increasing emissions from manufacturing and increasing overall emissions.

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Annex 2: Assessment and ranking of candidate actions

Each of the mitigation actions has been ranked according to criteria set out in our proposal:

- GHG emissions abatement and removal
- Accountability and verifiability
- Costs to land managers of implementation
- Technological constraints
- Benefits and Risks
- Socio-economic factors

Each of these criteria has been assessed based on evidence sourced from the available literature, supplemented by information provided by participants at the study workshop on 6 March and the expert judgement of the study team. Where information is available, this has been included within the action screening fiches (see Annex 2).

The evidence has been incorporated in to a matrix table (Table 3) to identify the greatest mitigation potential within actions and assess potential barriers to implementation.

The following section provides an overview of our approach and assessment of actions for each criteria. This information will form the basis for more detailed assessment of implementation and uptake at member state level for Task 2.

GHG emissions abatement and removal

Emissions abatement and removal potential for each action has been assessed and recorded as part of the matrix for ranking the appropriateness of implementation. For the purposes of ranking, we have reviewed the potential for reducing the emissions associated with the activity e.g. the percentage reduction of emissions from implementing an action. For sequestration we have assessed the t/ha carbon sequestration potential. Further analysis may be required to assess the CO_2 equivalent in real terms.

Evidence and data availability:

Estimates of the % reduction in emissions of N_2O, CH_4 and CO_2, or of the amount of C sequestered in soils, were taken as the mid points of the estimates reported in the Screening document.

For actions capable of reducing more than one GHG, such as optimising livestock feeds, the abatement potential for each gas was entered into the spreadsheet. No weighting according to the Global Warming Potential (GWP) potential of the gas was done. While, in some respects, this would have been an appropriate action, it would have weighted potential actions that abate N_2O very strongly and energy efficiency actions, which only reduce emissions of CO_2, very weakly. We considered it more appropriate to evaluate potential actions for their effectiveness in abating emissions from a given source, such as ruminant livestock, manure storage or farm machinery, so that emissions from all sources could potentially be reduced. Weighting according to GWP would have effectively selected only those actions with the potential to reduce emissions of N_2O. However, given the nature of the spreadsheet, actions could be weighted according to the GWP of the gases abated to provide an alternative assessment of the actions.

For actions for which our review did not elicit any measured or estimated abatement potentials we used our expert judgement to provide one. The actions for which expert judgement was used were:

- Soil and nutrient management plans.
- Improved nitrogen efficiency.
- Biological N fixation in rotations and in grass mixes.
- Maintain soil pH at suitable levels for crop/grass production.
- Carbon auditing tools.
- Anaerobic digestion (to reduce GHG emissions during manure storage).

The applicability of potential actions was mainly based on expert judgement. We only found reported estimates of potential applicability for:

- New agroforestry.
- Use of sexed semen for breeding dairy replacements.

Accountability and verifiability

There are two measures of accountability that we have reviewed. One is the ability to account for resultant changes of implementation of an action in GHG inventories based on IPCC guidelines. The other is accountability and verification of implementation through CAP.

IPCC Inventory accountability

There are two measures of accountability that we have reviewed. One is the ability to account for resultant changes of implementation of an action in GHG inventories based on IPCC guidelines. The other is accountability and verification of implementation through CAP.

The IPCC provides guidelines on GHG inventory methodologies these are set out on the box below.

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 Guidelines for National Greenhouse Gas Inventories (Volume 4)

The ability to assess the impact of GHG reductions, within the inventory accounting guidelines varies depending on the action and the associated data availability. In some cases the theoretical and practical abatement cannot be realised in the inventory due to constraints on accounting methods and data collection.

Most of the land use actions reviewed are relatively straight forward to account for as there is a physical change in the land use that can be observed, recorded and reported. Likewise with crop production measures provide some change in system that has an activity that can be identified and an appropriate emissions reduction number can be applied.

The difficulty occurs when we assess actions that are efficiency measures or that do not have a direct impact in their own right (carbon auditing). For example, all of the livestock actions are efficiency measures that may have a positive impact on GHG emissions at a farm scale but there is no baseline to measure against. Tier 3 approaches can account for these actions but the data recording requirements are laborious.

CAP verification

If actions are to be supported under the CAP, they must be able to be controlled and verified on the ground. Typically, these on the ground checks are of a (risk-based) sample of beneficiaries but for some types of investment all projects will be checked. In some cases farmers must provide evidence of required activities, such as nutrient management plans, stock movement details, grazing dates.

The assessment here has identified the extent to which such the actions identified are suited to these types of checks and controls. Where issues have been identified but the action has significant mitigation potential and could be supported under the CAP, the issues will be investigated further under Task 2 to see whether there are ways of resolving these issues.

Costs of implementation

Under this category the costs associated with the implementation of each mitigation action by the land manager have been assessed. Three broad categories of costs have been considered: capital costs (up front investments, for example for machinery or infrastructure); recurring costs (for example for specific more labour intensive management, record keeping etc); and opportunity costs (the income and costs for a farmer of undertaking the mitigation action compared with the income and costs of carrying on with existing management). Where there may be longer-term cost savings associated with the adoption of specific actions, these have also been identified.

Evidence and data availability: Evidence has been sourced from the available literature, supplemented by information provided by participants at the study workshop on 6 March and the expert judgement of the study team. Where information is available, this has been included within the action screening fiches (see Annex 2).

What is apparent from our review is the very limited availability of data on costs associated with individual mitigation actions. We had intended to break down the costs according to broad geographical region where relevant for particular measures, but this has not proved possible.

Nonetheless it is clear that the costs of the different 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. These may be short term adjustment costs required to adopt a new form of management or longer term permanent changes in cost structures as a result of the sustained use of new management methods over a longer period of time. In the first instance, the adjustment cost may comprise both investments of time by the farmer and / or physical investment in new equipment / buildings / livestock or both. Longer term costs may arise in cases where more sophisticated and more expensive equipment is needed on a more permanent basis, where yields or stocking densities need to be reduced or where certain soils need to be taken out of production or managed in a different way. For example, where peat soils need to be taken out of arable cropping, and perhaps converted to grassland, there could be long-term reductions in gross margins per hectare as a result of less profitable production regimes, as well as the one-off machinery and labour costs associated with conversion. There will also be opportunity costs related to the foregoing of future income streams.

However, the evidence also shows that a number of the actions reviewed could represent cost savings for farmers or foresters because they increase the overall profitability of the enterprise. This includes actions such as improvements in livestock health, where improvements in soil health lead to increased yields and where planning nutrient inputs more carefully leads to a reduced use of fertilisers and hence cost savings on the volume purchased.

In other cases the situation is less clear, for example where cost savings might be feasible due to reduced inputs, energy use etc but where crop yields might decrease. The market situations and costs of management in different parts of the EU will also have an impact which it is not easy to discern.

Where these sorts of actions have been supported via the CAP, particularly under the agri-environment scheme, the per hectare payment rates offered in different Member States provide an indication of the scale of the costs involved in adopting such actions. This is due to the fact that such payment rates are calculated on the basis of income foregone plus additional costs (with up to 20% of the payment also able to reflect transaction costs). A study carried out in 2011 (Hart *et al.,* 2011) looked at the payments rates for a range of environmental actions in a selection of RDPs (25 for agricultural actions and 16 for forestry actions) covering regions with different geographical, topographical and economic characteristics. It is only possible to compare a few of the management actions supported under the CAP directly with those screened for this exercise. For example, based on information from eight RDPs, the costs of converting arable to grassland ranged from €101/ha (in HU) to €733/ha (UK –England). The average across all eight RDPs was €313/ha and the median payment rate was €298/ha. For afforestation of agricultural land, the figures (from 11 RDPs) ranged from €133/ha (in Spain) to €7,000/ha in the Netherlands, with an average rate of €1,976/ha and a median of €1,862/ha.

Source: Based on information in the screening fiches, supplemented by NERI (2006); Hart *et al.,* (2011); Török *et al.,* (2011); Underwood and Poláková (2013).

Assessment:

Our assessment has identified for each action whether or not the different types of costs associated with its implementation are ‘high’, ‘medium’ or ‘low’ and where there is a potential for cost savings.

The evidence suggests that the majority of climate mitigation actions assessed are likely to have very low opportunity costs associated with them, particularly as many of the actions are likely to encourage more efficient means of production, particularly in relation to input use. Where high opportunity costs occur, these tend to be associated with actions that require significant land use changes, which could change the nature of the farming enterprise quite significantly depending on the scale at which the action is implemented. These sorts of actions include for example the conversion of arable to grassland, peatland rewetting or restoration and woodland creation.

The other main category of costs associated with these actions is the upfront capital costs required. These relate to:

- machinery and equipment costs, for example specialised machinery for zero tillage in order to plant seeds in undisturbed soil and crop residues;
- infrastructure costs, for example the installation of modern slurry storage facilities with sufficient storage capacity; and
- seed or plant costs for habitat creation, for example establishing grassland, tree planting for woodland creation or agroforestry or peatland restoration.

An issue that is often raised in relation to actions that require upfront investment in new equipment/machinery (e.g. precision machinery) or infrastructure (e.g. slurry storage) is that the profit margins of many farming enterprises are too small to enable the investment in new equipment that would, in the long term, generate savings that would exceed the initial capital cost. This is an issue that will be reviewed further under Task 2 in relation to specific actions.

Where high costs are identified, this does not necessarily mean that these actions should not be considered further, rather that they need further investigation. Indeed, it may be that these are amongst the actions that would be a priority for funding through the CAP, because they are the least likely to be adopted without incentives.

Technological Constraints

In ranking actions we have reviewed the potential technological constraints associated with implementing actions. Technical constraints were assessed on the basis of:

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

The review of land use actions highlighted no technical constraints to implementation. However, there may be an over estimation of the knowledge of some farmers in this area and there is likely to be a requirement for advice and training to maximise the benefits of land use changes.

With crop production actions, there were also minimal technical constraints to implementation. Minimum and zero tillage systems are well established and there are a wide variety of mechanical cultivation options available. Ceasing burning of crop residues and leaving crop residues on the surface are very basic actions and require little or no technological development or training. Equally the use of catch and cover crops was regarded as requiring no technical advancement but again benefits could be optimised by improving knowledge and understanding. The use of biochar was regarded as an emerging technology with limitations of the supply of the material and guidance on the usage.

Actions relating to livestock production were more mixed in terms of requirements for greater technology and understanding with all of the actions requiring some degree of training to realise the benefits. The use of feed additives, sexed semen and breeding low methane ruminant animals are all areas requiring further technological advancement before widespread implementation could be achieved.

Manure, fertiliser and soil management actions are generally uninhibited by technological constraints with the exception of the use of urease and nitrification inhibitors. These are constrained in terms of technology understanding and cost. Energy actions are generally well understood although the application of appropriate anaerobic digestion technology is required and an increased understanding of this would lead to improved implementation.

Co-benefits and Risks

We have reviewed possible co benefits and risks associated with implementation of each of the actions reviewed through the screening process. Our categorisation of the potential benefits and risks and a short description is detailed in Table 1 below.

Table 1: Benefits and Risks

Benefit/Risk area	Description
Climate Adaptation	Would implementation of the action have a positive impact on a farmer or a farm systems ability to adapt to negative impacts of climate change or encourage beneficial changes in farm systems?
Biodiversity	Would the action lead to benefits or negative impacts on habitats and biodiversity?
Water Impacts	Does an action have an impact on: a. Water resources such as increased or reduced soil water retention or flood risk b. Positive or negative impacts on water quality from pollutants such as nitrates and pesticides.
Impacts on Production	What are the impact of an action on overall production? Will it lead in increased or decreased total production or impact on production efficiency
CO_2 (e) leakage	Linked to impacts on production, what is the risk of displacing GHG when implementing an action?

Benefits and risks have been reviewed qualitatively through the process of screening and this information has been supplemented through the feedback from the project workshop on the 6th March. Generally, the balance of secondary impacts tends to be positive but this does vary according to the area of benefit and risk and to the specific action. There are also links to other criteria reviewed such as productivity and cost impacts.

The area where we observe the greatest associated benefits and least risks are relating to adaptation. Based on the information collected only none of the action assessed presented a potential risk to the adaptive capacity of farm businesses. Most are thought to have a beneficial impact but a small number will have minimal impacts. Similarly, biodiversity and water impacts are generally positive.

The area where the greatest risks occur are relating to impacts on production and the related carbon leakage. Risks in these areas were mostly identified in relation to the Land Use actions due to displaced production. But equally, the greatest benefits are associated with land use actions in the areas of adaptation, biodiversity, water (both quality and resources)

Socio-economic barriers

Under this category, we assess the potential socio-economic barriers to uptake of the mitigation actions by farmers and foresters across the EU. The main types of barriers identified and that have been assessed include: lack of awareness or understanding of the climate action; the lack of availability of advice; the absence of evidence on (or visibility of) the benefits of the action both in terms of its greenhouse gas abatement potential or its impacts on the farming system in terms of productivity; the social acceptability of the action amongst the wider public; and the scale at which implementation is necessary – for example where actions require action at a broader scale than is the responsibility of the farmer/forester.

It should be noted that institutional barriers to supporting such actions via policy are not addressed here. These are addressed under Task 2, where the potential for and feasibility of supporting the climate actions via policy measures are assessed.

***Evidence and data availability*:**

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[1]; Kim and Neff, 2009[2]). 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)[3] 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, be important contributors to reducing greenhouse gas emissions, but have little or no access to the relevant extension services (Keenleyside *et al.,* 2012)[4]. 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. Some of these farmers, especially in south-eastern and Mediterranean areas of the EU, will be managing low–intensity farming systems using permanent grassland and permanent crops, which may already be providing climate services (for example, if C sequestration is taking place on such land, or if grazed ground cover is reducing the risk of fire, and resulting GHG emissions, in permanent crops, e.g. olives, carob or adjacent forest). Alternatively, there may be much greater potential in such regions to reduce GHG emissions by using inputs more efficiently.

The lack of visibility of climate benefits can also sometimes be a barrier to uptake of climate actions, sue to the fact that, unlike many other forms of environmental land management, such as semi-natural habitat management and creation GHG emissions and C sequestration are largely invisible,. 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. Information provision alone may not be sufficient, however. In some cases, farmers and foresters may also require technical support and training to implement climate actions in practice.

Of course, even where sufficient advice, training and evidence is available there may still be reluctance to change established cropping patterns, farming/forest production systems and land use. Farming systems are a functional matrix of many different activities on different parcels of land and changes in one activity will have knock-on effects on many others and on costs/income. Receptivity to changes to management therefore will depend upon the nature and scale of these impacts.

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[1] 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

[2] 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

[3] 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

[4] 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.

There is very little evidence on the social acceptability or not of specific climate actions. However, inferences can be made. For example, the use of biochar may not be socially acceptable (at least in the short-term) due to the technical problems in finding a clean the manufacturing process. The pyrolysis of biomass produces not just biochar but also 'syngas' and toxins, which are unlikely to be socially acceptable from a health perspective. Another example is the use of antimicrobial feed additives, ionophores. These are currently banned for use in the EU and have been associated with some undesirable side effects, although are used elsewhere. The use of hormones is also unlikely to be socially unacceptable. For example bovine somatrophin (BsT) is used to improve the feed conversion of ruminant livestock in the USA. By reducing the feed intake required to produce a kilogram of meat or milk, this can reduce GHG emissions. However, consumer concerns mean that it is not currently used in the EU.

***Assessment*:** The assessment at this stage simply determines whether or not a particular barrier has been identified in the literature as being an issue for the uptake of the climate mitigation action. It is recognised that barriers can differ significantly with the socio-economic characteristics of the farm/forest holding (including the production system, holding size and tenure and the capacity of the farmer and the business) and this more fine-grained analysis will be carried out as part of Task 2.

The assessment shows the following:

- Awareness – there appears to be fairly good levels of awareness of many of the climate actions identified, particularly where they are actions that have been promoted for a number of years (sometimes for other environmental objectives rather than climate mitigation). Those areas where there is a lack of awareness tends to be those that are more technical in nature, for example some of the actions relating to livestock breeding, using feed additives and optimising feed strategies as well as some of those concerning manure, fertiliser and soil management, for example. More could also be done to raise awareness about the benefits of agroforestry, reduced and zero tillage as well as improving crop rotations in areas where these could be beneficial;
- For those actions where there is a lack of awareness there is generally also an issue with the availability of advice and often also an issue with the availability to farmers/foresters of evidence about the climate benefits and/or impacts of the actions of their farming system. However, the evidence shows that investment in advice and training continues to be important to ensure uptake of those actions where awareness already exists.
- There are very few of the actions that are considered to be socially unacceptable currently. Those where a potential issue has been identified are: reduced/zero tillage; applying biochar to soils; the use of some feed additives; and the use of nitrification inhibitors.

The existence of a socio-economic barrier is not necessarily an indication that the climate action should not be promoted more widely. Where lack of awareness, advice and information about the benefits of climate actions is identified, these can be overcome through the use of relevant policy tools, such as putting in place suitable advisory services and training, which can be funded through the CAP. These options are investigated further under Task 2. However, where actions are considered to be socially unacceptable currently, there is more of a question as to whether these types of actions should be promoted, particularly in the short term.

Ranking: overall assessment

Table 3 provides a high level assessment of actions against each of the ranking criteria. The purpose of the high level assessment is to provide an overview of the appropriateness of each action and highlight the areas that could provide the greatest challenges in implementation.

The ranking criteria are broken down into relevant sub categories as detailed in Table 2 below:

Table 2: Ranking sub criteria

GHG abatement and removal				**Accountability / Verifiability**		**Likely costs of Implementation to land manager**			**Technological constraints**			**Benefits**				**Risks**					**Socio-economic barriers**				
Nitrous Oxide	Methane	Carbon	Carbon sequestered - tCO2	According to IPCC guidance	In relation to CAP rules	Investment	Recurring (annual)	Opportunity costs (revenue	Emerging technology not yet	Issues with availability of	Lack of training to operate	Climate adaptation	Biodiversity	Water - availability / pollution	Production effects/ efficiency	Climate adaptation	Biodiversity	Water - availability / pollution	Production effects/ efficiency	Production leakage	Lack of awareness	Availability of advice	Lack of evidence / visibility of	Socially unacceptable at	Scale of operation - e.g.

Table 3: Ranking actions, high level assessment.

Area	Climate Action	GHG abatement and removal	Accountability / Verifiability	Capital Costs	Ongoing Costs	Tech constraints	Benefits	Risks	Socio-economic barriers
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	+							

Area	Climate Action	GHG abatement and removal	Accountability / Verifiability	Capital Costs	Ongoing Costs	Tech constraints	Benefits	Risks	Socio-economic barriers
Nutrient & Soil management	Soil and nutrient management plans	+	IPCC barriers			Knowledge			
	Use of nitrification inhibitors	+++							
	Improved nitrogen efficiency	+				Knowledge			
	Biological N fixation in rotations and in grass mixes	+							
Energy	Carbon auditing tools	+	IPCC barriers						
	Increased energy efficiency	++							

Legend			
+++	Highly effective		No/Limited barriers
++	Moderately effective		Some barriers, possible to overcome
+	Minimally effective		Significant barriers, challenging to overcome

Annex 3: Member State Mitigation Potential Information Tables

Please note the following points when reviewing the following tables.

- The mitigation potentials provided should be viewed as indicative and are based on estimated uptake factors.
- Mitigation potential is in addition to existing activity and based on 'expert judgment' of the realistic uptake with additional policy intervention.
- Uptake factors are explained in detail in Table 54 and Table 55 of the report.
- Mitigation potentials for each action in each of the following member state tables is detailed and compared in section 4.3 and 4.4 of the report. Table 55 provides a comparative analysis.
- In the tables below, inventory category analysis refers to **the main category when looking at whether it was identified as a key category, the current tier used, and the ability to demonstrate mitigation.** More detailed analysis of the sub-category impacts are reported in Chapter 3 of the report for each mitigation action under 'Reporting the mitigation effect'.
- The mitigation potentials stated are the median values. High and low values are also reported in Table 53 and Table 56 of the report.
- Farm level barriers and opportunities for relevant CAP measures are replicated in each table. These are fully explored in Chapter 3 of the report for each of the mitigation actions assessed.

Table 4: Austria Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	69	69	Arable area: 1500 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 1	Yes	Short	Short/ medium
New agroforestry	16	16	Arable area + area of permanent grassland (excluding LFA): 2100 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 2	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.0027	0.0027	Land with >30% SOC: 0.015 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Not provided	No	Short	Short /medium/ long
Woodland planting	52	52	Arable area + area of permanent grassland: 3200 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 1	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	150	150	Woodland area: 3800 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 3	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	14	140	Woodland area: 3800 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 3	No	Short	Short
Reduced tillage	0.52	2.6	Arable area: 1500 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 2	Yes	Short	Short
Zero tillage	1	5.2	Arable area: 1500 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 2	Yes	Short	Short
Leaving crop residues on the soil surface	17	17	Arable area: 1500 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 2	No	Short	Short
Ceasing to burn crop residues and vegetation	0.62	0.62	Mitigation potential is based on elimination of all burning where it	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	Tier 1	Yes	Short	Short

			currently occurs									
Use cover/catch crops	17	170	Arable area: 1500 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 2	No	Short	Short
Livestock disease management	2.4	130	Number of total livestock: 6200 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.72	36	Number of dairy cattle: 530 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.23	1.1	Number of ruminants: 3100 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	1.2	42	Number of cattle: 1200 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.46	14	Number of total livestock: 6200 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	1.1	170	Land in agricultural production: 3200 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2)	N_2O emissions from	No	N/A	No	Short	Short/ medium/ long

				farmers are likely to be a barrier where this action is not already adopted.	• Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)						
Use of nitrification inhibitors	13	930	Land in arable or grassland production (excluding LFAs): 2100 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	1.7	170	Land in agricultural production: 3200 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	27	140	Land in arable or grassland production (excluding LFAs): 2100 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	No		Short
Carbon auditing tools	11	450	Land in agricultural production: 3200 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	1.2	60	Land in agricultural production: 3200 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 2	Yes	Short	Short/ medium/ long

Table 5: Belgium Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	43	43	Arable area: 890 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 1	Yes	Short	Short/ medium
New agroforestry	7.3	7.3	Arable area + area of permanent grassland (excluding LFA): 2100 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.002	0.002	Land with >30% SOC: 0.012 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Tier 1	Yes	Short	Short/ medium/ long
Woodland planting	23	23	Arable area + area of permanent grassland: 1400 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 2	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	24	24	Woodland area: 590 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	No	Tier 2	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	2.2	22	Woodland area: 590 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	No	Tier 2	No	Short	Short
Reduced tillage	0.32	1.6	Arable area: 890 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Zero tillage	0.64	3.2	Arable area: 890 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Leaving crop residues on the soil surface	10	10	Arable area: 890 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	No	Tier 1	Yes	Short	Short
Ceasing to burn crop residues and vegetation	0	0	N/A: there are currently no emissions from burning	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	N/A	No	Short	Short
Use cover/catch crops	10	100	Arable area: 890 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	No	N/A	No	Short	Short

				positive or negative depending on the system.							
Livestock disease management	3.2	160	Number of total livestock: 9000 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.81	24	Number of dairy cattle: 500 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.25	0.75	Number of ruminants: 2700 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	1.3	33	Number of cattle: 2500 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.38	15	Number of total livestock: 9000 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	1.2	190	Land in agricultural production: 1400 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

Use of nitrification inhibitors	12	870	Land in arable or grassland production (excluding LFAs): 1300 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	1.9	190	Land in agricultural production: 1400 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	32	160	Land in arable or grassland production (excluding LFAs): 1300 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	14	420	Land in agricultural production: 1400 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	3.2	140	Land in agricultural production: 1400 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 1	Yes	Short	Short/ medium/ long

Table 6: Bulgaria Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	160	160	Arable area: 3400 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 1	Yes	Short	Short/ medium
New agroforestry	27	27	Arable area + area of permanent grassland (excluding LFA): 4800 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0	0	Land with >30% SOC: 0 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Tier 1	Yes	Short	Short/ medium/ long
Woodland planting	87	87	Arable area + area of permanent grassland: 5300 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 2	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	140	140	Woodland area: 3600 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 1	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	13	130	Woodland area: 3600 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 1	No	Short	Short
Reduced tillage	1.2	6	Arable area: 3400 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Zero tillage	2.4	12	Arable area: 3400 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Leaving crop residues on the soil surface	39	39	Arable area: 3400 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Ceasing to burn crop residues and vegetation	34	34	Mitigation potential is based on elimination of all burning where it	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	Tier 1	Yes	Short	Short

			currently occurs							
Use cover/catch crops	40	400	Arable area: 3400 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	No	N/A	No	Short	Short
Livestock disease management	1.3	52	Number of total livestock: 2900 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.21	1.1	Number of dairy cattle: 310 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.088	0	Number of ruminants: 2300 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	0.48	4.8	Number of cattle: 570 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.3	18	Number of total livestock: 2900 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long

Soil and nutrient management plans	1.4	220	Land in agricultural production: 5300 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long
Use of nitrification inhibitors	17	1200	Land in arable or grassland production (excluding LFAs): 4800 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	2.2	220	Land in agricultural production: 5300 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	36	180	Land in arable or grassland production (excluding LFAs): 4800 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	9.8	98	Land in agricultural production: 5300 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	0.73	22	Land in agricultural production: 5300(kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 2	Yes	Short	Short/ medium/ long

Table 7: Cyprus Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	7.5	7.5	Arable area: 160 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	No	N/A	Yes	Short	Short/ medium
New agroforestry	0.87	0.87	Arable area + area of permanent grassland (excluding LFA): 160 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	N/A	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0	0	Land with >30% SOC: 0 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	N/A	No	Short	Short/ medium/ long
Woodland planting	2.8	2.8	Arable area + area of permanent grassland: 170 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	No	Not provided	Yes	Short	Short / medium/ long

Preventing deforestation and removal of farmland trees	7.2	7.2	Woodland area: 180 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	No	Not provided	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	0.65	6.5	Woodland area: 180 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	No	N/A	No	Short	Short
Reduced tillage	0.056	0.28	Arable area: 160 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	N/A	Yes	Short	Short
Zero tillage	1.9	19	Arable area: 160 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	N/A	Yes	Short	Short
Leaving crop residues on the soil surface	1.8	1.8	Arable area: 160 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	No	N/A	Yes	Short	Short
Ceasing to burn crop residues and vegetation	0.7	0.7	Mitigation potential is based on elimination of all burning where it	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	Tier 1	Yes	Short	Short

			currently occurs								
Use cover/catch crops	1.8	18	Arable area: 160 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	No	Tier 1	No	Short	Short
Livestock disease management	0.25	10	Number of total livestock: 1100 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.024	0.12	Number of dairy cattle: 24 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.013	0	Number of ruminants: 680 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	0.073	0.73	Number of cattle: 56 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.077	4.6	Number of total livestock: 1100 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long

Soil and nutrient management plans	0.12	19	Land in agricultural production: 170 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long
Use of nitrification inhibitors	1.6	110	Land in arable or grassland production (excluding LFAs): 160 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	0.19	19	Land in agricultural production: 170 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	3.2	16	Land in arable or grassland production (excluding LFAs): 160 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	1.2	12	Land in agricultural production: 170 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	0.12	3.6	Land in agricultural production: 170 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 2	No	Short	Short/ medium/ long

Table 8: Czech Republic Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	140	140	Arable area: 3000 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	No	Tier 2	Yes	Short	Short/ medium
New agroforestry	21	21	Arable area + area of permanent grassland (excluding LFA): 3600 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.0049	0.0049	Land with >30% SOC: 0.028 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	N/A	No	Short	Short/ medium/ long
Woodland planting	67	67	Arable area + area of permanent grassland: 4100 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	No	Tier 1	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	110	110	Woodland area: 2700 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 1	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	9.8	98	Woodland area: 2700 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 1	No	Short	Short
Reduced tillage	1.1	5.4	Arable area: 3000 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Zero tillage	2.2	11	Arable area: 3000 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Leaving crop residues on the soil surface	35	35	Arable area: 3000 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Ceasing to burn crop residues and vegetation	0	0	N/A: there are currently no emissions from burning	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	N/A	No	Short	Short

Use cover/catch crops	35	350	Arable area: 3000 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 1	No	Short	Short
Livestock disease management	1.7	78	Number of total livestock: 3400 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.51	7.6	Number of dairy cattle:380 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.15	0.15	Number of ruminants: 1500 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	0.76	11	Number of cattle: 1300 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.33	17	Number of total livestock: 3400 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	1.7	270	Land in agricultural production: 4100 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

Use of nitrification inhibitors	21	1500	Land in arable or grassland production (excluding LFAs): 3600 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	2.7	270	Land in agricultural production: 4100 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	44	220	Land in arable or grassland production (excluding LFAs): 3600 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	12	240	Land in agricultural production: 4100 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	0.28	10	Land in agricultural production: 4100 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry /Fisheries CO_2	Yes	Tier 3	Yes	Short	Short/ medium/ long

Table 9: Germany Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	590	590	Arable area: 12000 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	No	Not provided	Yes	Short	Short/ medium
New agroforestry	88	88	Arable area + area of permanent grassland (excluding LFA): 15000 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.063	0.063	Land with >30% SOC: 0.36 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	Yes	Tier 1	Yes	Short	Short/ medium/ long
Woodland planting	280	280	Arable area + area of permanent grassland: 17000 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Not provided	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	440	440	Woodland area: 11000 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 2	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	40	400	Woodland area: 11000 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 2	No	Short	Short
Reduced tillage	4.5	22	Arable area: 12000 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Zero tillage	8.9	45	Arable area: 12000 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Leaving crop residues on the soil surface	140	140	Arable area: 12000 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Ceasing to burn crop residues and vegetation	0	0	N/A: there are currently no emissions from burning	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	N/A	No	Short	Short

Use cover/catch crops	150	1500	Arable area: 12000 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 1	No	Short	Short
Livestock disease management	16	860	Number of total livestock: 43000 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	5.2	260	Number of dairy cattle: 4400 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	1.5	7.5	Number of ruminants: 15000 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 3	No	Medium	Medium/ long
Feed additives for ruminant diets	7.8	270	Number of cattle: 13000 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 3	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	1.4	42	Number of total livestock: 43000 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 3	No	Medium	Short/ medium/ long
Soil and nutrient management plans	14	2300	Land in agricultural production: 17000 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

Use of nitrification inhibitors	180	12000	Land in arable or grassland production (excluding LFAs): 15000 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	23	2300	Land in agricultural production: 17000 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	370	1800	Land in arable or grassland production (excluding LFAs): 15000 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	100	4200	Land in agricultural production: 17000 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	9.3	460	Land in agricultural production: 17000 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 1	Yes	Short	Short/ medium/ long

Table 10: Denmark Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	120	120	Arable area: 2500 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 2	Yes	Short	Short/ medium
New agroforestry	14	14	Arable area + area of permanent grassland (excluding LFA): 2700 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Not provided	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.0016	0.0016	Land with >30% SOC: 0.009 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	Yes	Tier 2	Yes	Short	Short/ medium/ long
Woodland planting	45	45	Arable area + area of permanent grassland: 2700 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	No	Not provided	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	20	20	Woodland area: 490 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Not provided	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	1.8	18	Woodland area: 490 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Not provided	No	Short	Short
Reduced tillage	0.9	4.5	Arable area: 2500 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Not provided	Yes	Short	Short
Zero tillage	1.8	9	Arable area: 2500 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Not provided	Yes	Short	Short
Leaving crop residues on the soil surface	29	29	Arable area: 2500 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Ceasing to burn crop residues and vegetation	3.4	3.4	Mitigation potential is based on elimination of all burning where it	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	Tier 1	Yes	Short	Short

			currently occurs								
Use cover/catch crops	29	290	Arable area: 2500 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Not provided	No	Short	Short
Livestock disease management	2.5	140	Number of total livestock: 14000 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.7	35	Number of dairy cattle: 570 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.19	0.95	Number of ruminants: 1700 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	1.1	38	Number of cattle: 1600 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.2	5.9	Number of total livestock: 14000 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	1.8	280	Land in agricultural production: 2700 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2).	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

					• Agri-environment-climate payments (M10.1)						
Use of nitrification inhibitors	22	1500	Land in arable or grassland production (excluding LFAs): 2700 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	2.8	280	Land in agricultural production: 2700 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	45	230	Land in arable or grassland production (excluding LFAs): 2700 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	14	580	Land in agricultural production: 2700 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	3.1	160	Land in agricultural production: 2700 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	No	Tier 1	Yes	Short	Short/ medium/ long

Table 11: Estonia Summary Table

Mitigation actions (MA)	Mitigation potential t/ha/year carbon seq: Using 1% of possible MA uptake	Mitigation potential t/ha/year carbon seq: Using expert judgement to estimate MA uptake	Applicability: e.g. area of land or number of livestock (units)	Implementation: Farm level - barriers and opportunities	Implementation: Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	IPCC Accounting: Main IPCC (1996) Category Impacted	IPCC Accounting: Identified as a Key cat in 2012	IPCC Accounting: Ability to account: Current tier used	IPCC Accounting: Ability to account: Ability to demonstrate mitigation in the inventory	Timescales: Timescale (for implementation by land manager)	Timescales: Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	28	28	Arable area: 580 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 1	Yes	Short	Short/ medium
New agroforestry	4.3	4.3	Arable area + area of permanent grassland (excluding LFA): 730 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.18	0.18	Land with >30% SOC: 1.1 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	Yes	Tier 2	Yes	Short	Short/ medium/ long
Woodland planting	14	14	Arable area + area of permanent grassland: 830 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 1	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	91	91	Woodland area: 2300 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 1	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	8.3	83	Woodland area: 2300 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 1	No	Short	Short
Reduced tillage	0.21	1	Arable area: 580 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Zero tillage	0.42	2.1	Arable area: 580 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Leaving crop residues on the soil surface	6.7	6.7	Arable area: 580 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Ceasing to burn crop residues and vegetation	0	0	N/A: there are currently no emissions from burning	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	Tier 1	No	Short	Short

Use cover/catch crops	6.8	68	Arable area: 580 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 1	No	Short	Short
Livestock disease management	0.32	14	Number of total livestock: 600 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.096	1.4	Number of dairy cattle: 99 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.031	0.031	Number of ruminants: 240 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	0.16	2.4	Number of cattle: 240 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.054	2.7	Number of total livestock: 600 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	0.26	41	Land in agricultural production: 830 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

Use of nitrification inhibitors	3	210	Land in arable or grassland production (excluding LFAs): 730 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	0.41	41	Land in agricultural production: 830 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	6.7	34	Land in arable or grassland production (excluding LFAs): 730 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	2	40	Land in agricultural production: 830 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	0.38	13	Land in agricultural production: 830 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 1	Yes	Short	Short/ medium/ long

Table 12: Greece Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	160	160	Arable area: 3300 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 1	Yes	Short	Short/ medium
New agroforestry	22	22	Arable area + area of permanent grassland (excluding LFA): 3500 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0	0	Land with >30% SOC: 0 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Tier 1	Yes	Short	Short/ medium/ long
Woodland planting	72	72	Arable area + area of permanent grassland: 4400 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	No	Not provided	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	150	150	Woodland area: 3700 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 2	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	13	130	Woodland area: 3700 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 2	No	Short	Short
Reduced tillage	1.2	5.9	Arable area: 3300 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Zero tillage	10	93	Arable area: 3300 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Leaving crop residues on the soil surface	38	38	Arable area: 3300 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Ceasing to burn crop residues and vegetation	44	44	Mitigation potential is based on elimination of all burning where it	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	Not provided	Yes	Short	Short

			currently occurs								
Use cover/catch crops	39	390	Arable area: 3300 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 1	No	Short	Short
Livestock disease management	2.3	91	Number of total livestock: 16000 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.2	1	Number of dairy cattle: 140 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.23	0	Number of ruminants: 15000 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	1.2	12	Number of cattle: 660 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.3	18	Number of total livestock: 16000 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	1.7	260	Land in agricultural production: 4400 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2).	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

					• Agri-environment-climate payments (M10.1)						
Use of nitrification inhibitors	15	1000	Land in arable or grassland production (excluding LFAs): 3500 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	2.6	260	Land in agricultural production: 4400 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	43	220	Land in arable or grassland production (excluding LFAs): 3500 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	14	140	Land in agricultural production: 4400 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	1.3	39	Land in agricultural production: 4400 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 2	Yes	Short	Short/ medium/ long

Table 13: Spain Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	840	840	Arable area: 18000 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 1	Yes	Short	Short/ medium
New agroforestry	130	130	Arable area + area of permanent grassland (excluding LFA): 19000 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.0024	0.0024	Land with >30% SOC: 0.014 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Tier 1	Yes	Short	Short/ medium/ long
Woodland planting	430	430	Arable area + area of permanent grassland: 26000 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 2	Yes	Short	Short / medium/ long

Preventing deforestation and removal of farmland trees	580	580	Woodland area: 14000 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 1	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	53	530	Woodland area: 14000 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 1	No	Short	Short
Reduced tillage	6.3	31	Arable area: 18000 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 2	Yes	Short	Short
Zero tillage	110	1100	Arable area: 18000 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 2	Yes	Short	Short
Leaving crop residues on the soil surface	200	200	Arable area: 18000 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Not provided	No	Short	Short
Ceasing to burn crop residues and vegetation	520	520	Mitigation potential is based on elimination of all burning where it	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	Not provided	No	Short	Short

			currently occurs								
Use cover/catch crops	210	2100	Arable area: 18000 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 2	No	Short	Short
Livestock disease management	10	510	Number of total livestock: 53000 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	1.8	53	Number of dairy cattle: 850 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.71	2.1	Number of ruminants: 27000 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	No	Tier 1	No	Medium	Medium/ long
Feed additives for ruminant diets	3.8	96	Number of cattle: 6000 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	No	Tier 1	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.76	30	Number of total livestock: 53000 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	No	Tier 1	No	Medium	Short/ medium/ long
Soil and nutrient management plans	6.4	1000	Land in agricultural production: 26000 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2).	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

					• Agri-environment-climate payments (M10.1)						
Use of nitrification inhibitors	69	4800	Land in arable or grassland production (excluding LFAs): 19000 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	No	Tier 2	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	10	1000	Land in agricultural production: 26000 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	No	Tier 2	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	160	820	Land in arable or grassland production (excluding LFAs): 19000 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	No	Tier 2	Yes		Short
Carbon auditing tools	57	1700	Land in agricultural production: 26000 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	16	730	Land in agricultural production: 26000 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	N/A	Yes	Short	Short/ medium/ long

Table 14: Finland Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	110	110	Arable area: 2300 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 1	Yes	Short	Short/ medium
New agroforestry	12	12	Arable area + area of permanent grassland (excluding LFA): 2300 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	3.2	3.2	Land with >30% SOC: 19 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Tier 1	Yes	Short	Short/ medium/ long
Woodland planting	39	39	Arable area + area of permanent grassland: 2400 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 2	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	900	900	Woodland area: 22000 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 2	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	82	820	Woodland area: 22000 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 2	No	Short	Short
Reduced tillage	0.84	4.2	Arable area: 2300 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Zero tillage	1.7	8.4	Arable area: 2300 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Leaving crop residues on the soil surface	27	27	Arable area: 2300 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Ceasing to burn crop residues and vegetation	0.51	0.51	Mitigation potential is based on elimination of all burning where it	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	Tier 1	Yes	Short	Short

			currently occurs								
Use cover/catch crops	27	270	Arable area: 2300 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 1	No	Short	Short
Livestock disease management	1.2	67	Number of total livestock: 2300 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.19	9.7	Number of dairy cattle: 280 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.06	0.3	Number of ruminants: 940 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	0.58	20	Number of cattle: 900 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.21	6.2	Number of total livestock: 2300 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	1.2	190	Land in agricultural production: 2100 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2).	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

					• Agri-environment-climate payments (M10.1)						
Use of nitrification inhibitors	15	1000	Land in arable or grassland production (excluding LFAs): 2400 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	1.9	190	Land in agricultural production: 2100 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	31	160	Land in arable or grassland production (excluding LFAs): 2400 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	8.6	340	Land in agricultural production: 2100 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	2.3	110	Land in agricultural production: 2100 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 3	Yes	Short	Short/ medium/ long

Table 15: France Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account Current tier used	Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	960	960	Arable area: 20000 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 2	Yes	Short	Short/ medium
New agroforestry	150	150	Arable area + area of permanent grassland (excluding LFA): 25000 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.0062	0.0062	Land with >30% SOC: 0.035 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Not provided	No	Short	Short/ medium/ long
Woodland planting	490	490	Arable area + area of permanent grassland: 30000 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 2	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	620	620	Woodland area: 25000 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 2	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	57	570	Woodland area: 25000 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 2	No	Short	Short
Reduced tillage	7.2	36	Arable area:20000 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 2	Yes	Short	Short
Zero tillage	14	72	Arable area: 20000 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 2	Yes	Short	Short
Leaving crop residues on the soil surface	230	230	Arable area: 20000 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 2	No	Short	Short
Ceasing to burn crop residues and vegetation	32	32	Mitigation potential is based on elimination of all burning where it	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	Yes	Not provided	Yes	Short	Short

			currently occurs								
Use cover/catch crops	240	2400	Arable area: 20000 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 2	No	Short	Short
Livestock disease management	24	1300	Number of total livestock: 43000 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	7.1	350	Number of dairy cattle: 3700 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	2.1	10	Number of ruminants: 28000 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	11	370	Number of cattle: 19000 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	2.5	75	Number of total livestock: 43000 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	16	2500	Land in agricultural production: 30000 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2).	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

					• Agri-environment-climate payments (M10.1)						
Use of nitrification inhibitors	170	12000	Land in arable or grassland production (excluding LFAs): 25000 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	25	2500	Land in agricultural production: 30000 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 2	No	short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	410	2100	Land in arable or grassland production (excluding LFAs): 25000 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 2	Yes		Short
Carbon auditing tools	130	5400	Land in agricultural production: 30000 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	17	850	Land in agricultural production: 30000 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 2	Yes	Short	Short/ medium/ long

Table 16: Croatia Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	48	48	Arable area: 1000 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 1	Yes	Short	Short/ medium
New agroforestry	6.9	6.9	Land in arable or grassland production: 1400* (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0	0	Land with >30% SOC: 0 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Tier 1	No	Short	Short/ medium/ long
Woodland planting	22	22	Arable area + area of permanent grassland: 1400 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 2	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	86	86	Woodland area: 2100 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 1	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	7.8	78	Woodland area: 2100 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 1	No	Short	Short
Reduced tillage	0.36	1.8	Arable area: 1000 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	N/A	Yes	Short	Short
Zero tillage	0.72	3.6	Arable area: 1000 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	N/A	Yes	Short	Short
Leaving crop residues on the soil surface	12	12	Arable area: 1000 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 2	Yes	Short	Short
Ceasing to burn crop residues and vegetation	0	0	N/A: there are currently no emissions from burning	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	N/A	No	Short	Short

Use cover/catch crops	12	120	Arable area: 1000 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 1	No	Short	Short
Livestock disease management	0.73	29	Number of total livestock: 2300 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.17	0.84	Number of dairy cattle: 180 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.059	0	Number of ruminants: 1100 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	0.31	3.1	Number of cattle: 450 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.15	8.7	Number of total livestock: 2300 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	0.73	110	Land in agricultural production: 1400 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

Use of nitrification inhibitors	8.6	600	Land in arable or grassland production: 1400* (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long	* LFA **
Improved nitrogen efficiency	1.1	110	Land in agricultural production: 1400 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long	
Bio N fixation in rotations and in grass mixes	19	93	Land in arable or grassland production: 1400* (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	No		Short	
Carbon auditing tools	5.1	51	Land in agricultural production: 1400 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long	
Improved on-farm energy efficiency	1	30	Land in agricultural production: 1400 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 1	No	Short	Short/ medium/ long	

*The area of grassland in LFAs is not subtracted for this MS, as it has been for other MSs, because the LFA area data are not available for this MS.

Table 17: Hungary Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	230	230	Arable area: 4800 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 2	Yes	Short	Short/ medium
New agroforestry	30	30	Arable area + area of permanent grassland (excluding LFA): 5600 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 2	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.000063	0.000063	Land with >30% SOC: 0.00036 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Tier 1	Yes	Short	Short/ medium/ long
Woodland planting	96	96	Arable area + area of permanent grassland: 5800 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 2	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	78	78	Woodland area: 1900 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 2	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	7	70	Woodland area: 1900 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 2	No	Short	Short
Reduced tillage	1.7	8.6	Arable area: 4800 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 2	Yes	Short	Short
Zero tillage	3.4	17	Arable area: 4800 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 2	Yes	Short	Short
Leaving crop residues on the soil surface	56	56	Arable area: 4800 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	No	Tier 2	Yes	Short	Short
Ceasing to burn crop residues and vegetation	0	0	N/A: there are currently no emissions from burning	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	Tier 1	Yes	Short	Short

Use cover/catch crops	56	560	Arable area: 4800 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 2	No	Short	Short
Livestock disease management	2	89	Number of total livestock: 5300 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.38	5.7	Number of dairy cattle: 250 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.1	0.1	Number of ruminants: 2000 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	No	Tier 1	No	Medium	Medium/ long
Feed additives for ruminant diets	0.56	8.5	Number of cattle: 710 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	No	Tier 1	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.43	21	Number of total livestock: 5300 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	No	Tier 1	No	Medium	Short/ medium/ long
Soil and nutrient management plans	1.8	280	Land in agricultural production: 5800 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

Use of nitrification inhibitors	22	1500	Land in arable or grassland production (excluding LFAs): 5600 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	No	Tier 2	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	2.8	280	Land in agricultural production: 5800 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	No	Tier 2	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	46	230	Land in arable or grassland production (excluding LFAs): 5600 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	No	Tier 2	Yes		Short
Carbon auditing tools	13	260	Land in agricultural production: 5800 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	1.3	45	Land in agricultural production: 5800 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	No	Tier 1	No	Short	Short/ medium/ long

Table 18: Ireland Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	49	49	Arable area: 1000 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 1	Yes	Short	Short/ medium
New agroforestry	22	22	Arable area + area of permanent grassland (excluding LFA): 1800 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.22	0.22	Land with >30% SOC: 1.2 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Tier 1	Yes	Short	Short/ medium/ long
Woodland planting	71	71	Arable area + area of permanent grassland: 4300 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 3	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	26	26	Woodland area: 650 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	No	Tier 3	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	2.4	24	Woodland area: 650 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	No	Tier 3	No	Short	Short
Reduced tillage	0.37	1.9	Arable area: 1000 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	Tier 1	No	Short	Short
Zero tillage	0.74	3.7	Arable area: 1000 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	Tier 1	No	Short	Short
Leaving crop residues on the soil surface	12	12	Arable area: 1000 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	No	Tier 1	Yes	Short	Short
Ceasing to burn crop residues and vegetation	0	0	N/A: there are currently no emissions from burning	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	N/A	Yes	Short	Short

Use cover/catch crops	12	120	Arable area: 1000 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	No	Tier 1	No	Short	Short
Livestock disease management	6.3	320	Number of total livestock: 11000(000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	2.2	66	Number of dairy cattle: 1000 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.65	2	Number of ruminants: 9500 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	No	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	3.3	83	Number of cattle: 6200 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	No	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.23	9.3	Number of total livestock: 11000 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	No	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	2.3	350	Land in agricultural production: 4300 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

Use of nitrification inhibitors	17	1200	Land in arable or grassland production (excluding LFAs): 1800 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	3.5	350	Land in agricultural production: 4300 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 2	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	58	290	Land in arable or grassland production (excluding LFAs): 1800 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 2	Yes		Short
Carbon auditing tools	27	810	Land in agricultural production: 4300 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	1	47	Land in agricultural production: 4300 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 3	Yes	Short	Short/ medium/ long

Table 19: Italy Summary Table

Mitigation actions (MA)	Mitigation potential t/ha/year carbon seq: Using 1% of possible MA uptake	Mitigation potential t/ha/year carbon seq: Using expert judgement to estimate MA uptake	Applicability: e.g. area of land or number of livestock (units)	Implementation: Farm level - barriers and opportunities	Implementation: Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	IPCC Accounting: Main IPCC (1996) Category Impacted	IPCC Accounting: Identified as a Key cat in 2012	IPCC Accounting: Ability to account: Current tier used	IPCC Accounting: Ability to account: Ability to demonstrate mitigation in the inventory	Timescales: Timescale (for implementation by land manager)	Timescales: Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	490	490	Arable area: 10000 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	No	Tier 1	Yes	Short	Short/ medium
New agroforestry	73	73	Arable area + area of permanent grassland (excluding LFA): 12000 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.000013	0.000013	Land with >30% SOC: 0.000076 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	N/A	No	Short	Short/ medium/ long
Woodland planting	230	230	Arable area + area of permanent grassland: 14000 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 2	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	390	390	Woodland area: 9700 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 3	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	36	360	Woodland area: 9700 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 3	No	Short	Short
Reduced tillage	3.7	18	Arable area: 10000 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Zero tillage	7.3	37	Arable area: 10000 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Leaving crop residues on the soil surface	120	120	Arable area: 10000 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Ceasing to burn crop residues and vegetation	19	19	Mitigation potential is based on elimination of all burning where it	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	Yes	Tier 1	Yes	Short	Short

			currently occurs								
Use cover/catch crops	120	1200	Arable area: 10000 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 1	No	Short	Short
Livestock disease management	9.5	470	Number of total livestock: 24000 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	2.2	65	Number of dairy cattle: 1900 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.77	2.3	Number of ruminants: 15000 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	4	100	Number of cattle: 6100 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	1.8	70	Number of total livestock: 24000 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	5.8	910	Land in agricultural production: 14000 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2).	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

					• Agri-environment-climate payments (M10.1)						
Use of nitrification inhibitors	68	4800	Land in arable or grassland production (excluding LFAs): 12000 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	9.1	910	Land in agricultural production: 14000 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	150	750	Land in arable or grassland production (excluding LFAs): 12000 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	53	1600	Land in agricultural production: 14000 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	10	460	Land in agricultural production: 14000 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 3	Yes	Short	Short/ medium/ long

Table 20: Lithuania Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	96	96	Arable area: 2000 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 1	Yes	Short	Short/ medium
New agroforestry	15	15	Arable area + area of permanent grassland (excluding LFA): 2400 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	N/A	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.02	0.02	Land with >30% SOC: 0.12 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	N/A	No	Short	Short /medium/ long
Woodland planting	49	49	Arable area + area of permanent grassland: 3000 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 1	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	85	85	Woodland area: 2100 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 1	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	7.7	77	Woodland area: 2100 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 1	No	Short	Short
Reduced tillage	0.72	3.6	Arable area: 2000 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	N/A	Yes	Short	Short
Zero tillage	1.4	7.2	Arable area: 2000 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	N/A	Yes	Short	Short
Leaving crop residues on the soil surface	23	23	Arable area: 2000 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Ceasing to burn crop residues and vegetation	0	0	N/A: there are currently no emissions from burning	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	N/A	Yes	Short	Short
Use cover/catch crops	24	240	Arable area: 2000 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 1	No	Short	Short

				positive or negative depending on the system.							
Livestock disease management	1.1	43	Number of total livestock: 1700 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.31	1.6	Number of dairy cattle: 370 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.087	0	Number of ruminants: 830 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	0.44	4.4	Number of cattle: 760 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.13	7.9	Number of total livestock: 1700 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	1.1	170	Land in agricultural production: 3000 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long
Use of nitrification inhibitors	13	920	Land in arable or grassland production (excluding	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long

			LFAs): 2400 (kha)	economic benefits to the farmer but they are proven to be effective in reducing GHG.							
Improved nitrogen efficiency	1.7	170	Land in agricultural production: 3000 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	28	140	Land in arable or grassland production (excluding LFAs): 2400 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	7.6	76	Land in agricultural production: 3000 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	0.15	4.5	Land in agricultural production: 3000 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 1	Yes	Short	Short/ medium/ long

Table 21: Luxembourg Summary Table

Mitigation actions (MA)	Mitigation potential t/ha/year carbon seq: Using 1% of possible MA uptake	Mitigation potential t/ha/year carbon seq: Using expert judgement to estimate MA uptake	Applicability: e.g. area of land or number of livestock (units)	Implementation: Farm level - barriers and opportunities	Implementation: Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	IPCC Accounting: Main IPCC (1996) Category Impacted	IPCC Accounting: Identified as a Key cat in 2012	IPCC Accounting: Ability to account: Current tier used	IPCC Accounting: Ability to account: Ability to demonstrate mitigation in the inventory	Timescales: Timescale (for implementation by land manager)	Timescales: Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	3	3	Arable area: 63 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 1	Yes	Short	Short/ medium
New agroforestry	0.62	0.62	Arable area + area of permanent grassland (excluding LFA): 66 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0	0	Land with >30% SOC: 0 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Tier 1	Yes	Short	Short/ medium/ long
Woodland planting	2	2	Arable area + area of permanent grassland: 120 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 2	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	3.1	3.1	Woodland area: 77 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 1	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	0.28	2.8	Woodland area: 77 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 1	No	Short	Short
Reduced tillage	0.023	0.11	Arable area: 63 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Zero tillage	0.045	0.23	Arable area: 63 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Leaving crop residues on the soil surface	0.73	0.73	Arable area: 63 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Ceasing to burn crop residues and vegetation	0	0	N/A: there are currently no emissions from burning	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	N/A	Yes	Short	Short

Use cover/catch crops	0.74	7.4	Arable area: 63 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 1	No	Short	Short
Livestock disease management	0.2	10	Number of total livestock: 290 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.065	1.9	Number of dairy cattle: 45 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.018	0.053	Number of ruminants: 200 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	0.09	2.2	Number of cattle: 190 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.016	0.65	Number of total livestock: 290 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	0.11	17	Land in agricultural production: 120 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

Use of nitrification inhibitors	1.1	78	Land in arable or grassland production (excluding LFAs): 66 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	0.17	17	Land in agricultural production: 120 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	2.7	14	Land in arable or grassland production (excluding LFAs): 66 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	1	30	Land in agricultural production: 120 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	0.077	3.4	Land in agricultural production: 120 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 2	Yes	Short	Short/ medium/ long

Table 22: Latvia Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	58	58	Arable area: 1200 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Not provided	Yes	Short	Short/ medium
New agroforestry	9.9	9.9	Arable area + area of permanent grassland (excluding LFA): 1400 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.088	0.088	Land with >30% SOC: 0.51 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	Yes	Tier 1	Yes	Short	Short/ medium/ long
Woodland planting	32	32	Arable area + area of permanent grassland: 1900 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 2	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	120	120	Woodland area: 3000 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 2	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	11	110	Woodland area: 3000 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 2	No	Short	Short
Reduced tillage	0.43	2.2	Arable area: 1200 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Zero tillage	0.87	4.3	Arable area: 1200 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Leaving crop residues on the soil surface	14	14	Arable area: 1200 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Ceasing to burn crop residues and vegetation	0	0	N/A: there are currently no emissions from burning	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	N/A	No	Short	Short

Use cover/catch crops	14	140	Arable area: 1200 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 1	No	Short	Short
Livestock disease management	0.5	20	Number of total livestock: 840 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.16	0.8	Number of dairy cattle: 170 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.05	0	Number of ruminants: 460 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	0.26	2.6	Number of cattle: 390 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.061	3.7	Number of total livestock: 840 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	0.53	83	Land in agricultural production: 1900 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

Use of nitrification inhibitors	6.4	450	Land in arable or grassland production (excluding LFAs): 1400 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	0.83	83	Land in agricultural production: 1900 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	14	68	Land in arable or grassland production (excluding LFAs): 1400 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	3.6	36	Land in agricultural production: 1900 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	Yes	Short	Short/ medium/ long
Improved on-farm energy efficiency	0.56	17	Land in agricultural production: 1900 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 2	No	Short	Short/ medium/ long

Table 23: Malta Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	0.46	0.46	Arable area: 9.6 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	No	Not provided	Yes	Short	Short/ medium
New agroforestry	0.054	0.054	Arable area + area of permanent grassland: 11* (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0	0	Land with >30% SOC: 0 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	N/A	No	Short	Short/ medium/ long
Woodland planting	0.17	0.17	Arable area + area of permanent grassland: 11 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	No	Not provided	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	0.035	0.035	Woodland area: 0.86 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 1	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	0.0032	0.032	Woodland area: 0.86 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 1	No	Short	Short
Reduced tillage	0.0034	0.017	Arable area: 9.6 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	Tier 1	Yes	Short	Short
Zero tillage	0.0069	0.034	Arable area: 9.6 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	Tier 1	Yes	Short	Short
Leaving crop residues on the soil surface	0.11	0.11	Arable area: 9.6 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	No	Tier 1	No	Short	Short
Ceasing to burn crop residues and vegetation	0	0	N/A: there are currently no emissions from burning	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	N/A	Yes	Short	Short

Use cover/catch crops	0.11	1.1	Arable area: 9.6 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	No	Tier 1	No	Short	Short
Livestock disease management	0.03	1.2	Number of total livestock: 93 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.0073	0.036	Number of dairy cattle: 6.7 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.0019	0	Number of ruminants: 34 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	No	Tier 1	No	Medium	Medium/ long
Feed additives for ruminant diets	0.011	0.11	Number of cattle: 16 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	No	Tier 1	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.0019	0.11	Number of total livestock: 93 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	No	Tier 1	No	Medium	Short/ medium/ long
Soil and nutrient management plans	0.0089	1.4	Land in agricultural production: 11 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

Use of nitrification inhibitors	0.11	8	Arable area + area of permanent grassland: 11* (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long	* LFA
Improved nitrogen efficiency	0.014	1.4	Land in agricultural production: 11 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long	
Bio N fixation in rotations and in grass mixes	0.23	1.1	Arable area + area of permanent grassland: 11* (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short	
Carbon auditing tools	0.12	1.2	Land in agricultural production: 11 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long	
Improved on-farm energy efficiency	0.034	1	Land in agricultural production: 11 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Not provided	Yes	Short	Short/ medium/ long	

*The area of grassland in LFAs is not subtracted for this MS, as it has been for other MSs, because the LFA area data are not available for this MS.

Table 24: Netherlands Summary Table

Mitigation actions (MA)	Mitigation potential t/ha/year carbon seq: Using 1% of possible MA uptake	Mitigation potential t/ha/year carbon seq: Using expert judgement to estimate MA uptake	Applicability: e.g. area of land or number of livestock (units)	Implementation: Farm level - barriers and opportunities	Implementation: Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	IPCC Accounting: Main IPCC (1996) Category Impacted	IPCC Accounting: Identified as a Key cat in 2012	IPCC Accounting: Ability to account: Current tier used	IPCC Accounting: Ability to account: Ability to demonstrate mitigation in the inventory	Timescales: Timescale (for implementation by land manager)	Timescales: Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	52	52	Arable area: 1100 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	No	Tier 1	Yes	Short	Short/ medium
New agroforestry	10	10	Arable area + area of permanent grassland (excluding LFA): 1800 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	N/A	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.0042	0.0042	Land with >30% SOC: 0.024 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	N/A	Yes	Short	Short/ medium/ long
Woodland planting	32	32	Arable area + area of permanent grassland: 1900 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 2	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	15	15	Woodland area: 360 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 2	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	1.3	13	Woodland area: 360 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 2	No	Short	Short
Reduced tillage	0.39	2	Arable area: 1100 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	N/A	Yes	Short	Short
Zero tillage	0.79	3.9	Arable area: 1100 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	N/A	Yes	Short	Short
Leaving crop residues on the soil surface	13	13	Arable area: 1100 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	No	N/A	No	Short	Short
Ceasing to burn crop residues and vegetation	0	0	N/A: there are currently no emissions from burning	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	N/A	No	Short	Short

Use cover/catch crops	13	130	Arable area: 1100 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	No	N/A	No	Short	Short
Livestock disease management	5.6	310	Number of total livestock: 17000 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	1.7	85	Number of dairy cattle: 1500 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.45	2.3	Number of ruminants: 5400 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 3	No	Medium	Medium/ long
Feed additives for ruminant diets	2.5	86	Number of cattle: 4000 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 3	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.5	15	Number of total livestock: 17000 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 3	No	Medium	Short/ medium/ long
Soil and nutrient management plans	2	310	Land in agricultural production: 1900 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

Use of nitrification inhibitors	21	1500	Land in arable or grassland production (excluding LFAs): 1800 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	3.1	310	Land in agricultural production: 1900 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 2	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	51	260	Land in arable or grassland production (excluding LFAs): 1800 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 2	Yes		Short
Carbon auditing tools	24	950	Land in agricultural production: 1900 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	14	690	Land in agricultural production: 1900 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 1	Yes	Short	Short/ medium/ long

Table 25: Poland Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	650	650	Arable area: 14000 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	No	Tier 1	Yes	Short	Short/ medium
New agroforestry	88	88	Arable area + area of permanent grassland (excluding LFA): 15000 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.0078	0.0078	Land with >30% SOC: 0.045 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	Yes	Not provided	Yes	Short	Short/ medium/ long
Woodland planting	280	280	Arable area + area of permanent grassland: 17000 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 2	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	370	370	Woodland area: 9200 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 2	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	34	340	Woodland area: 9200 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 2	No	Short	Short
Reduced tillage	4.9	24	Arable area: 14000 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Zero tillage	9.7	49	Arable area: 14000 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Leaving crop residues on the soil surface	160	160	Arable area: 14000 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Ceasing to burn crop residues and vegetation	30	30	Mitigation potential is based on elimination of all burning where it currently occurs	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	Yes	Not provided	Yes	Short	Short

Use cover/catch crops	160	1600	Arable area: 14000 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 1	No	Short	Short
Livestock disease management	9	400	Number of total livestock: 20000 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	2.1	32	Number of dairy cattle: 2500 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.64	0.64	Number of ruminants: 5900 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	3.4	50	Number of cattle: 5500 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	2.4	120	Number of total livestock: 20000 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	7.1	1100	Land in agricultural production: 17000 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

Use of nitrification inhibitors	89	6300	Land in arable or grassland production (excluding LFAs): 15000 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	11	1100	Land in agricultural production: 17000 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	180	910	Land in arable or grassland production (excluding LFAs): 15000 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	55	1100	Land in agricultural production: 17000 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	16	540	Land in agricultural production: 17000 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Not provided	Yes	Short	Short/ medium/ long

Table 26: Portugal Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	100	100	Arable area: 2100 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Not provided	Yes	Short	Short/ medium
New agroforestry	17	17	Arable area + area of permanent grassland (excluding LFA): 2200 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	Not provided	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0	0	Land with >30% SOC: 0 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Not provided	Yes	Short	Short/ medium/ long
Woodland planting	54	54	Arable area + area of permanent grassland: 3300 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Not provided	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	140	140	Woodland area: 3600 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Not provided	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	13	130	Woodland area: 3600 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Not provided	No	Short	Short
Reduced tillage	0.76	3.8	Arable area: 2100 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	Not provided	Yes	Short	Short
Zero tillage	12	120	Arable area: 2100 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	No	Not provided	Yes	Short	Short
Leaving crop residues on the soil surface	24	24	Arable area: 2100 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	No	Not provided	No	Short	Short
Ceasing to burn crop residues and vegetation	43	43	Mitigation potential is based on elimination of all burning where it	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	Not provided	Yes	Short	Short

			currently occurs								
Use cover/catch crops	25	250	Arable area: 2100 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	No	Not provided	No	Short	Short
Livestock disease management	2.2	100	Number of total livestock: 6200 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.5	7.5	Number of dairy cattle: 250 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.2	0.2	Number of ruminants: 4200 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	1	15	Number of cattle: 1500 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.15	7.3	Number of total livestock: 6200 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	1	160	Land in agricultural production: 3300 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2).	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

					• Agri-environment-climate payments (M10.1)						
Use of nitrification inhibitors	9.6	670	Land in arable or grassland production (excluding LFAs): 2200 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	1.6	160	Land in agricultural production: 3300 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	26	130	Land in arable or grassland production (excluding LFAs): 2200 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	11	220	Land in agricultural production: 3300 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	1.5	53	Land in agricultural production: 3300 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 2	Yes	Short	Short/ medium/ long

Table 27: Romania Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	450	450	Arable area: 9400 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	No	Tier 1	Yes	Short	Short/ medium
New agroforestry	72	72	Arable area + area of permanent grassland (excluding LFA): 13000 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.00073	0.00073	Land with >30% SOC: 0.0042 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Not provided	Yes	Short	Short/ medium/ long
Woodland planting	230	230	Arable area + area of permanent grassland: 14000 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Not provided	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	260	260	Woodland area: 6400 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 2	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	23	230	Woodland area: 6400 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 2	No	Short	Short
Reduced tillage	3.4	17	Arable area: 9400 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Zero tillage	6.8	34	Arable area: 9400 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Leaving crop residues on the soil surface	110	110	Arable area: 9400 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Ceasing to burn crop residues and vegetation	1010	110	Mitigation potential is based on elimination of all burning where it	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	Tier 1	Yes	Short	Short

			currently occurs								
Use cover/catch crops	110	1100	Arable area: 9400 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 1	No	Short	Short
Livestock disease management	5.4	220	Number of total livestock: 18000 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.75	3.7	Number of dairy cattle: 1300 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.55	0	Number of ruminants: 12000 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	No	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	3	30	Number of cattle: 2300 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	No	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.61	36	Number of total livestock: 18000 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	No	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	2.9	460	Land in agricultural production: 14000 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2)	N_2O emissions from	No	N/A	No	Short	Short/ medium/ long

					• Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)						
Use of nitrification inhibitors	33	2300	Land in arable or grassland production (excluding LFAs): 13000 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	4.6	460	Land in agricultural production: 14000 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	74	370	Land in arable or grassland production (excluding LFAs): 13000 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	27	270	Land in agricultural production: 14000 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	1.7	52	Land in agricultural production: 14000 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 1	Yes	Short	Short/ medium/ long

Table 28: Sweden Summary Table

Mitigation actions (MA)	Mitigation potential t/ha/year carbon seq: Using 1% of possible MA uptake	Mitigation potential t/ha/year carbon seq: Using expert judgement to estimate MA uptake	Applicability: e.g. area of land or number of livestock (units)	Implementation: Farm level - barriers and opportunities	Implementation: Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	IPCC Accounting: Main IPCC (1996) Category Impacted	IPCC Accounting: Identified as a Key cat in 2012	IPCC Accounting: Ability to account: Current tier used	IPCC Accounting: Ability to account: Ability to demonstrate mitigation in the inventory	Timescales: Timescale (for implementation by land manager)	Timescales: Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	130	130	Arable area: 2700 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	No	Tier 3	Yes	Short	Short/ medium
New agroforestry	16	16	Arable area + area of permanent grassland (excluding LFA): 2900 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 3	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	2.2	2.2	Land with >30% SOC: 13 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Tier 2	Yes	Short	Short/ medium/ long
Woodland planting	51	51	Arable area + area of permanent grassland: 3100 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 3	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	1100	1100	Woodland area: 27000 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 2	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	100	1000	Woodland area: 27000 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 2	No	Short	Short
Reduced tillage	0.95	4.8	Arable area: 2700 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 3	Yes	Short	Short
Zero tillage	1.9	9.5	Arable area: 2700 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 3	Yes	Short	Short
Leaving crop residues on the soil surface	31	31	Arable area: 2700 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 3	No	Short	Short
Ceasing to burn crop residues and vegetation	43	43	Mitigation potential is based on elimination of all burning where it	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	N/A	No	Short	Short

			currently occurs								
Use cover/catch crops	31	310	Arable area: (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 3	No	Short	Short
Livestock disease management	1.8	100	Number of total livestock: 3500 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.53	27	Number of dairy cattle: 330 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.17	0.84	Number of ruminants: 2000 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	0.95	33	Number of cattle: 1500 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.22	6.6	Number of total livestock: 3500 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	1.5	240	Land in agricultural production: 3100 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2).	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

					• Agri-environment-climate payments (M10.1)						
Use of nitrification inhibitors	15	1000	Land in arable or grassland production (excluding LFAs): 2900 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	2.4	240	Land in agricultural production: 3100 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	39	200	Land in arable or grassland production (excluding LFAs): 2900 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	11	460	Land in agricultural production: 3100 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	2.2	110	Land in agricultural production: 3100 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 2	Yes	Short	Short/ medium/ long

Table 29: Slovenia Summary Table

Mitigation actions (MA)	Mitigation potential t/ha/year carbon seq: Using 1% of possible MA uptake	Mitigation potential t/ha/year carbon seq: Using expert judgement to estimate MA uptake	Applicability: e.g. area of land or number of livestock (units)	Implementation: Farm level - barriers and opportunities	Implementation: Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	IPCC Accounting: Main IPCC (1996) Category Impacted	IPCC Accounting: Identified as a Key cat in 2012	IPCC Accounting: Ability to account: Current tier used	IPCC Accounting: Ability to account: Ability to demonstrate mitigation in the inventory	Timescales: Timescale (for implementation by land manager)	Timescales: Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	10	10	Arable area: 220 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 2	Yes	Short	Short/ medium
New agroforestry	2.6	2.6	Arable area + area of permanent grassland (excluding LFA): 240 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0	0	Land with >30% SOC: 0 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Tier 1	Yes	Short	Short/ medium/ long
Woodland planting	8.4	8.4	Arable area + area of permanent grassland: 510 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 2	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	51	51	Woodland area: 1300 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 3	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	4.6	46	Woodland area: 1300 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 3	No	Short	Short
Reduced tillage	0.078	0.39	Arable area: 220 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Zero tillage	0.16	0.78	Arable area: 220 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Leaving crop residues on the soil surface	2.5	2.5	Arable area: 220 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Ceasing to burn crop residues and vegetation	0	0	N/A: there are currently no emissions from burning	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	N/A	No	Short	Short

Use cover/catch crops	2.5	25	Arable area: 220 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 1	No	Short	Short
Livestock disease management	0.65	29	Number of total livestock: 1000 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.2	3.1	Number of dairy cattle: 110 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.047	0.047	Number of ruminants: 630 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	0.24	3.7	Number of cattle: 470 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.069	3.4	Number of total livestock: 1000 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	0.24	38	Land in agricultural production: 510 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

Use of nitrification inhibitors	2.9	200	Land in arable or grassland production (excluding LFAs): 240 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	0.38	38	Land in agricultural production: 510 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	6.2	31	Land in arable or grassland production (excluding LFAs): 240 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	2.8	56	Land in agricultural production: 510 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	0.31	11	Land in agricultural production: 510 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 3	Yes	Short	Short/ medium/ long

Table 30: Slovakia Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	71	71	Arable area: 1500 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 1	Yes	Short	Short/ medium
New agroforestry	11	11	Arable area + area of permanent grassland (excluding LFA): 1800 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	0.000036	0.000036	Land with >30% SOC: 0.00021 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	N/A	Yes	Short	Short/ medium/ long
Woodland planting	36	36	Arable area + area of permanent grassland: 2200 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 2	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	79	79	Woodland area: 1900 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 1	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	7.1	71	Woodland area: 1900 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 1	No	Short	Short
Reduced tillage	0.53	2.7	Arable area: 1500 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Zero tillage	1.1	5.3	Arable area: 1500 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	Yes	Short	Short
Leaving crop residues on the soil surface	17	17	Arable area: 1500 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 1	No	Short	Short
Ceasing to burn crop residues and vegetation	0	0	N/A: there are currently no emissions from burning	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	N/A	No	Short	Short

Use cover/catch crops	17	170	Arable area: 1500 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 1	No	Short	Short
Livestock disease management	0.78	35	Number of total livestock: 1800 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	0.19	2.9	Number of dairy cattle: 180 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	0.064	0.064	Number of ruminants: 980 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	0.33	5	Number of cattle: 520 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	0.19	9.5	Number of total livestock: 1800 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	0.65	100	Land in agricultural production: 2200 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	Yes	N/A	No	Short	Short/ medium/ long

Use of nitrification inhibitors	7.9	550	Land in arable or grassland production (excluding LFAs): 1800 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	1	100	Land in agricultural production: 2200 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	17	83	Land in arable or grassland production (excluding LFAs): 1800 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes		Short
Carbon auditing tools	4.9	98	Land in agricultural production: 2200 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	0.13	4.6	Land in agricultural production: 2200 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 2	Yes	Short	Short /medium/ long

Table 31: United Kingdom Summary Table

	Mitigation potential t/ha/year carbon seq		Applicability	Implementation		IPCC Accounting				Timescales	
Mitigation actions (MA)	Using 1% of possible MA uptake	Using expert judgement to estimate MA uptake	e.g. area of land or number of livestock (units)	Farm level - barriers and opportunities	Where it is appropriate to promote this climate mitigation action, the relevant CAP measures include:	Main IPCC (1996) Category Impacted	Identified as a Key cat in 2012	Ability to account: Current tier used	Ability to account: Ability to demonstrate mitigation in the inventory	Timescale (for implementation by land manager)	Timescale (of mitigation effect)
Conversion of arable land to grassland to sequester carbon in the soil	290	290	Arable area: 6100 (kha)	Opportunity cost and potential capital cost of establishment of livestock enterprises, secondary impacts from increased grazing livestock, reduced production efficiency.	• GAEC 1 buffer trips along watercourses • GAEC 5 minimum land management to limit soil erosion • EFAs under Pillar 1 greening requirements • Agri-environment-climate objectives (M4.4) • Agri-environment-climate payments (M10.1) • Potential relevance of conversion to and maintenance of organic farming systems (M11.1 and 11.2)	Land converted to grassland	Yes	Tier 3	Yes	Short	Short/ medium
New agroforestry	82	82	Arable area + area of permanent grassland (excluding LFA): 11000 (kha)	Lack of practical experience, establishment costs and the perception of ongoing management costs.	• Greening: EFAs can include areas of agroforestry • Demonstration activities and information for farmers (M1.2) • RDP support for agroforestry (M8.2) • 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 (M16.5) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 3	Yes	Short	Short/ medium
Wetland/ peatland conservation/ restoration	1.1	1.1	Land with >30% SOC: 6.2 (kha)	Restoration requires significant and long term changes in farming systems. Costs range based on the productivity of the land.	• Greening: designate environmentally sensitive permanent grasslands on peat and wetland in Natura 2000 areas and on carbon rich soils elsewhere, to prohibit conversion or ploughing • GAEC 7 retention of landscape features • Agri-environment-climate objectives (M4.4) for restoration work • Agri-environment-climate payments (M10.1) • Compensation payment for Natura 2000 farmland areas (M12.1) • Compensation payment for agricultural areas (M12.3) within river basin management plans • Support for ongoing environmental practices (M16.5)	Wetlands remaining wetlands	No	Tier 1	Yes	Short	Short/ medium/ long
Woodland planting	260	260	Arable area + area of permanent grassland: 16000 (kha)	Significant and long term change in system required for land in agricultural production. Set up costs are high but policy measures providing funding for capital cost and management payments are long established.	• Greening: EFAs can be relevant areas created with RDP or equivalent national support • 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)	Land converted to forestland	Yes	Tier 3	Yes	Short	Short/ medium/ long

Preventing deforestation and removal of farmland trees	110	110	Woodland area: 2800 (kha)	To a large extent the action is currently implemented through existing restrictions on felling and removal of farmland trees.	• GAEC 7 retention of landscape features • SMR 2 (Birds Directive) and SMR 3 (Habitats Directive) standards where these prohibit the removal woodland or trees and shrubs • EFAs under Pillar 1 greening requirements can be existing hedges, trees in lines or groups and isolated trees	Forestland remaining forestland	Yes	Tier 3	Yes	Short	Short
Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land	10	100	Woodland area: 2800 (kha)	Limited barriers but there may be some costs associated with management.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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 (M16.2)	Forestland remaining forestland	Yes	Tier 3	No	Short	Short
Reduced tillage	2.2	11	Arable area: 6100 (kha)	Specialist machinery required. Already widely used in arable systems with cost benefits widely stated as the reason for implementation, costs of crop protection can be higher as increased herbicides and fungicides may be required.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 3	Yes	Short	Short
Zero tillage	4.4	22	Arable area: 6100 (kha)	Specialist machinery required. Used in arable systems with cost benefits widely stated as the reason for implementation. Costs of crop protection can be higher as increased herbicides and fungicides may be required. Improved moisture retention stated as a benefit.	• GAEC 5 minimum land management to limit soil erosion. • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • 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) • Support for investments in agricultural holdings (M4.1) • EIP operational groups and pilot projects (M16.2)	Cropland remaining cropland - CO_2 removal	Yes	Tier 3	Yes	Short	Short
Leaving crop residues on the soil surface	71	71	Arable area: 6100 (kha)	May lead to increased pest and disease pressure.	• GAEC 6 maintenance of soil organic matter (to prevent burning of crop residues)	Cropland remaining cropland - CO_2 removal	Yes	Tier 3	No	Short	Short
Ceasing to burn crop residues and vegetation	0	0	N/A: there are currently no emissions from burning	Most member states have stopped this activity through Cross Compliance with the exception for phytosanitary reasons.	• GAEC 6 maintenance of soil organic matter • Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	Field burning of agricultural residues	No	Tier 1	No	Short	Short

Use cover/catch crops	72	720	Arable area: 6100 (kha)	Advisory activity may be needed to support successful establishment of cover crops. Estimates of financial impact on farm businesses vary significantly and could be positive or negative depending on the system.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	Cropland remaining cropland	Yes	Tier 3	No	Short	Short
Livestock disease management	14	750	Number of total livestock: 35000 (000 head)	Decisions will be based on economic drivers. Successful disease management schemes have been reliant on an integrated regional or national approach and climate impacts are viewed as a secondary benefit which is very difficult to measure.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service Possibly EIP operational groups and pilot projects (M16.2).	Enteric fermentation, CH_4	No	N/A	No	Short	Medium/ long
Use of sexed semen for breeding dairy replacements	3.5	180	Number of dairy cattle: 1900 (000 head)	Cost is likely to be a barrier at farm level and measuring and monitoring the direct impact on climate will be very challenging.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4 Cattle	No	N/A	No	Short	Medium/ long
Breeding lower methane emissions in ruminants	1.1	5.6	Number of ruminants: 31000 (000 head)	Breeding programmes for low emissions are relatively new and small scale. Breed establishment or integrating low GHG traits into existing herds/flocks are uncertain and take multiple livestock generations.	• No relevant CAP measures to support this mitigation action	Enteric fermentation, CH_4 ruminant species	Yes	Tier 2	No	Medium	Medium/ long
Feed additives for ruminant diets	5.8	200	Number of cattle: 8900 (000 head)	Barriers depend on the additive used. Hormones such as ionophores are prohibited. Barrier to adding fat and the use of probiotics are likely to be a lack of cost benefit.	• Demonstration activities and information (M1.2)	Enteric fermentation, CH_4	Yes	Tier 2	No	Medium	Short/ medium/ long
Optimised feeding strategies for livestock	1.3	40	Number of total livestock: 35000 (000 head)	Barriers to uptake will be the understanding of the farmers who are not already optimising feeding programmes for economic reasons.	• Demonstration activities and information (M1.2) • 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 • Possibly EIP operational groups and pilot projects (M16.2)	Manure management N_2O	Yes	Tier 2	No	Medium	Short/ medium/ long
Soil and nutrient management plans	9.5	1500	Land in agricultural production: 16000 (kha)	The benefits of good soils and nutrient management are well understood. However the perception of cost and knowledge of farmers are likely to be a barrier where this action is not already adopted.	• NVZ under Nitrates directive SMR 1 • GAEC 5 minimum land management to limit soil erosion • GAEC 6 maintenance of soil organic matter • Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service • Possibly EIP operational groups and pilot projects (M16.2). • Agri-environment-climate payments (M10.1)	N_2O emissions from managed soils	No	N/A	No	Short	Short/ medium/ long

Use of nitrification inhibitors	94	6600	Land in arable or grassland production (excluding LFAs): 11000 (kha)	No barriers in the implementation but some reports of residues being found in milk may create public health concerns that may need to be overcome. They do not provide economic benefits to the farmer but they are proven to be effective in reducing GHG.	• Agri-environment-climate payments (M10.1) to cover the additional costs to farmers (and possibly yield reductions) if the requirements for verification and payment control of RDP payments can be met	Direct soil emissions N_2O	Yes	Tier 1	No	Medium	Short/ medium/ long
Improved nitrogen efficiency	15	1500	Land in agricultural production: 16000 (kha)	No technological barriers other than knowledge and understanding of farmers. There are economic benefits of optimising N efficiency. The challenge is that the economic impact of under applying N is far greater than over applying.	• Demonstration activities and information actions (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service	N_2O emissions from managed soils	Yes	Tier 1	No	Short	Short/ medium/ long
Bio N fixation in rotations and in grass mixes	240	1200	Land in arable or grassland production (excluding LFAs): 11000 (kha)	This practice is well established in grassland systems and evidence suggests that it would be beneficial in arable systems as well. The availability of information and advice is likely to be a limiting factor.	• EFAs under Pillar 1 greening requirements can include crop diversification and use of N-fixing crops • Demonstration activities and information (M1.2) • Agri-environment-climate payments, as equivalence for EFAs (M10.1)	N_2O emissions from managed soils	Yes	Tier 1	Yes	Short	
Carbon auditing tools	78	3100	Land in agricultural production: 16000 (kha)	Carbon auditing tools are a useful guide but do not directly lead to reductions in GHG emissions. As a result, implementation of the action requires support. There may also be tech barriers in encouraging use of an IT based system.	• Demonstration activities and information (M1.2) • Farm and forestry advisory services (M2.2) to provide through the Member State's Farm Advisory Service: 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 • Possibly EIP operational groups and pilot projects (M16.2)	All agriculture	No	N/A	No	Short	Short/ medium/ long
Improved on-farm energy efficiency	6.3	310	Land in agricultural production: 16000 (kha)	Capital cost of changes and understanding improvements that could be made.	• Training and skills acquisition (M1.1) e.g. techniques to improve fuel efficiency such as eco-driving and tractor maintenance • Demonstration activities and information (M1.2), for example on developing a fuel use action plan • 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	Energy, fuel combustion, other sectors, Agriculture/ Forestry/ Fisheries CO_2	Yes	Tier 2	Yes	Short	Short/ medium/ long

Annex 4: Additional information on administrative effort

Table 1: Additional administrative costs/efforts required to introduce new or extend existing climate mitigation actions into Cross-Compliance

O	One-off cost
R	Recurring cost
-	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

Area	Climate Management Action (CMA)	GHG abatement and removal	Relevant action for Cross-compliance	Preparation				Implementation				Monitoring	
				Data Gathering and assembly		Measure design		Measure delivery		Control and verification		Monitoring and Evaluation	
				Extend existing	Introduce new	Extend existing	Introduce new	Extend existing	Introduce new	Extend existing	Introduce new	Extend existing	Introduce new
Land Use	Conversion of arable land to grassland to sequester carbon in the soil	++	Buffer strips in accordance with the N Directive	No additional administrative efforts should occur as this action should already be in place in all situations where relevant									
	Agroforestry, short rotation forestry	+	**N/A**										
	Wetland/peat land conservation/ restoration	+++	**N/A**										
	Woodland creation	+++	**N/A**										
	Woodland Management	+++	Refers to the inclusion of woody elements under GAEC7	1 (0) To review/source evidence to support inclusion of new elements	2-5 (O/R) Possibly to source evidence on need for new elements under GAEC 7 and may require new remote sensing data	1 (O) To consider any revisions to rules	1 (O) To determine which woody elements to include and where	1(O) Possible review required of guidance materials	1 (O/R) New guidance materials + advice via FAS	- Systems already in place	1 (O/R) Costs will depend on number of additional farms needing checks and controls. May require new remote sensing data	- Systems already in place	1 (R) Develop methods for new action and incorporate into existing M&E systems/ requirements
Crop Production	Reduced Tillage	+	N/A										
	Zero Tillage	+	N/A										
	Leaving Crop Residues on the soil surface	+	Could be introduced under GAEC4 (minimum soil cover)	1 (0) To review / source evidence on relevance in different situations	2-5 (O/R) To justify need to introduce action and may require remote sensing data for control purposes	1 (O) To target additional situations where action is appropriate	1 (O) Development of rules + control criteria	1(O) Possible review of guidance materials	1 (O/R) New guidance materials + advice via FAS	- Systems already in place	1 (O/R) Costs will depend on number of additional farms needing checks and controls. May require new remote sensing data	- Systems already in place	1 (R) Develop methods for new action and incorporate into existing M&E systems/ requirements
	Ceasing burning of vegetation & crop residues	+	Should be included already in all Member States (under GAEC6 usually)	No additional administrative efforts should occur as this action should already be in place in all situations where relevant									
	Use cover/catch crops and reduce bare fallow	+	Could be included under GAEC 4 (minimum soil cover) and possibly GAEC 5 - limiting soil erosion). Provisions are in place in some MSs already	1 (0) To review / source evidence on relevance in different situations	2-5 (O/R) To justify need to introduce action and may require remote sensing data for control purposes	1 (O) To target additional situations where action is appropriate	1 (O) Development of rules + control criteria	1(O) Possible review of guidance materials	1 (O/R) New guidance materials + advice via FAS	- Systems already in place	1 (O/R) Costs will depend on number of additional farms needing checks and controls. May require new remote sensing data	- Systems already in place	1 (R) Develop methods for new action and incorporate into existing M&E systems/ requirements
Livestock Production	Livestock disease management	++	N/A										
	Use of sexed semen for breeding dairy replacements	+	N/A										
	Breeding low methane emissions in ruminants	+	N/A										
	Use of feed additives	+	N/A										
	Optimise feed strategies	+	N/A										
Nutrient & Soil management	Soil and nutrient management plans	+	N/A										
	Use of urease inhibitors and next-generation nitrification inhibitors	+++	N/A										
	Improved nitrogen efficiency	+	N/A										

	Biological N fixation in rotations and in grass mixes	+	N/A										
Energy	Carbon auditing tools	+	N/A										
	Increased energy efficiency	++	N/A										

Table 2: Additional administrative costs/efforts required to introduce new or extend existing climate mitigation actions into Greening

O	One-off cost
R	Recurring cost
-	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

Area	Climate Management Action (CMA)	GHG abatement and removal	Relevant action for greening	Preparation				Implementation				Monitoring	
				Data Gathering and assembly		Measure design		Measure delivery		Control and verification		Monitoring and Evaluation	
				Extend existing	Introduce new	Extend existing	Introduce new	Extend existing	Introduce new	Extend existing	Introduce new	Extend existing	Introduce new
Land Use	Conversion of arable land to grassland to sequester carbon in the soil	++	Use of buffer strips to contribute to EFA	- If elected already no further action to take	2-5 (O/R) To justify rationale for introducing the action and may require remote sensing data for control purposes	- If elected already no further action to take	1 (O) Development of rules + control criteria	1(O) Possible review of guidance materials	1 (O/R) Potential extra time for processing IACS claims. New guidance materials + advice via FAS	1(O) Systems already in place. Possible extra time for additional control checks	1 (O/R) Costs will depend on number of additional checks and controls required. 5 if requires new remote sensing data	- Systems already in place	1 (R) Develop methods for new action and incorporate into existing M&E systems/ requirements
	Agroforestry, short rotation forestry	+	Use of agroforestry or SRC to contribute to EFA	- If elected already no further action to take	2-5 (O/R) To justify rationale for introducing the action and may require remote sensing data for control purposes	- If elected already no further action to take	1 (O) Development of rules + control criteria	1(O) Possible review of guidance materials	1 (O/R) Potential extra time for processing IACS claims. New guidance materials + advice via FAS	1(O) Systems already in place. Possible extra time for additional control checks	1 (O/R) Costs will depend on number of additional checks and controls required. 5 if requires new remote sensing data	- Systems already in place	1 (R) Develop methods for new action and incorporate into existing M&E systems/ requirements
	Wetland/peat land conservation/ restoration	+++	Environmentally sensitive permanent grassland (ESPG) includes wetland/peatland and other grassland on carbon rich soils.	- If elected already no further action to take	2-5 (O/R) To justify rationale for introducing the action and may require remote sensing data for control purposes	1 (O) To identify ESPG to be protected and update guidance	1 (O) Development of rules, target areas + control criteria	1(O) Possible review of guidance materials	1 (O/R) Potential extra time for processing IACS claims. New guidance materials + advice via FAS	1(O) Systems already in place. Possible extra time for additional control checks	1 (O/R) Costs will depend on number of additional checks and controls required. 5 if requires new remote sensing data	- Systems already in place	1 (R) Develop methods for new action and incorporate into existing M&E systems/ requirements
	Woodland creation	+++	N/A										
	Woodland Management	+++	Where woodland or woody landscape features are made eligible for EFA	- If elected already no further action to take	2-5 (O/R) To justify rationale for introducing the action and may require remote sensing data for control purposes	- If elected already no further action to take	1 (O) Development of rules + control criteria	1(O) Possible review of guidance materials	1 (O/R) Potential extra time for processing IACS claims. New guidance materials + advice via FAS	1(O) Systems already in place. Possible extra time for additional control checks	1 (O/R) Costs will depend on number of additional checks and controls required. 5 if requires new remote sensing data	- Systems already in place	1 (R) Develop methods for new action and incorporate into existing M&E systems/ requirements
Crop Production	Reduced Tillage	+	N/A										
	Zero Tillage	+	N/A										
	Leaving Crop Residues on the soil surface	+	N/A										
	Ceasing burning of vegetation & crop residues	+	N/A										
	Use cover/catch crops and reduce bare fallow	+	Use of cover crops or fallow used to contribute to EFA	- If elected already no further action to take	2-5 (O/R) To justify rationale for introducing the action and may require remote sensing data for control purposes	- If elected already no further action to take	1 (O) Development of rules + control criteria	1(O) Possible review of guidance materials	1 (O/R) Potential extra time for processing IACS claims. New guidance materials + advice via FAS	1(O) Systems already in place. Possible extra time for additional control checks	1 (O/R) Costs will depend on number of additional checks and controls required. 5 if requires new remote sensing data	- Systems already in place	1 (R) Develop methods for new action and incorporate into existing M&E systems/ requirements
Livestock Production	Livestock disease management	++	N/A										

	Use of sexed semen for breeding dairy replacements	+	N/A										
	Breeding low methane emissions in ruminants	+	N/A										
	Use of feed additives	+	N/A										
	Optimise feed strategies	+	N/A										
Nutrient & Soil management	Soil and nutrient management plans	+	N/A										
	Use of urease inhibitors and next-generation nitrification inhibitors	+++	N/A										
	Improved nitrogen efficiency	+	N/A										
	Biological N fixation in rotations and in grass mixes	+	N/A										
Energy	Carbon auditing tools	+	N/A										
	Increased energy efficiency	++	N/A										

Table 3: Additional administrative costs/efforts required to introduce new or extend existing climate mitigation actions into RDPs

O	One-off cost
R	Recurring cost
-	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

Area	Climate Management Action (CMA)	GHG abatement and removal	Relevant action for EAFRD	Preparation				Implementation				Monitoring	
				Data Gathering and assembly		Measure design		Measure delivery		Control and verification		Monitoring and Evaluation	
				Extend existing	Introduce new	Extend existing	Introduce new	Extend existing	Introduce new	Extend existing	Introduce new	Extend existing	Introduce new
Land Use	Conversion of arable land to grassland to sequester carbon in the soil	++	M10.1 (AECM) M11.1 (OF) if part of an organic system M4.4 – non-productive investments M1, M2 (advice/ training) to support M20 (EIP network) to support	1 (O) to inform decisions on how the CMA should be targeted in locations where it is not currently operating	3 (O) To provide evidence to justify rationale for introducing the action and inform decisions about the targeting of the action	1(O) Identification of additional areas to target.	1 (O) Development of prescriptions, target areas, payment rates + control criteria	1 (O/R) Revisions to scheme guidance. Possible additional costs for processing applications[1]	2 (O/R) Potential extra time to process applications. New guidance materials and advice. Training for advisers and delivery staff	1(O) Systems already in place. Possible extra time for additional control checks	1/2(R) Costs will depend on number of additional checks and controls required	- Systems already in place	1 (R) Develop methods / indicators for monitoring new action and incorporate into existing M&E systems/ requirements
	Agroforestry, short rotation forestry	+	M8.2 (agroforestry) M10.1 (AECM – for traditional systems unless covered by M15.1) M15.1 (Forest-env-climate – for traditional systems unless covered by M10.1) M4.4 (non-productive investments) M16 (Cooperation – pilots, joint action) M1, M2 (advice/ training) to support M20 (EIP network) to support	1(O) As above.	3/4 (O) Agroforestry likely to require research on costs / benefits and optimal management in different part of EU.	1(O) As above.	1 (O) As above	1 (O/R) As above	2 (O/R) As above	1(O) As above	1/2(R) As above	- As above	1 (R) As above
		+	M10.1 - AECM M1, M2 (advice/ training) to support M20 (EIP network) to support	1(O) As above.	3 (O) To provide evidence to justify rationale for introducing the action and inform decisions about the targeting of the action, particularly to avoid any detrimental impacts on other environmental priorities	1(O) As above.	1 (O) As above	1 (O/R) As above	2 (O/R) As above	1(O) As above	1/2(R) As above	- As above	1 (R) As above
	Wetland/peat land conservation/ restoration	+++	M10.1 – AECM M4.4 (non-productive investments) M8.5 – investments in improving forest ecosystem resilience and env value M12 – N2K and WFD payments M15.1 – FECM M16.5 – joint actions & 16.8 – forest mgt plans M1, M2 (advice/ training) to support M20 (EIP network) to support	1(O) As above.	3 (O) To provide evidence to justify rationale for introducing the action and inform decisions about the targeting of the action,	1(O) As above.	1 (O) As above	1 (O/R) As above	2 (O/R) As above	1(O) As above	1/2(R) As above	- As above	1 (R) As above
	Woodland creation	+++	M8.1 Afforestation M16.5 – joint actions & 16.8 – forest mgt plans M1, M2 (advice/ training) to support M20 (EIP network) to support	1(O) As above.	3 (O) To provide evidence to justify rationale for introducing the action and inform decisions about the targeting of the action,	1(O) As above.	1 (O) As above	1 (O/R) As above	2 (O/R) As above	1(O) As above	1/2(R) As above	- As above	1 (R) As above

	Woodland Management	+++	M8 – investments in forest area devpt and improving viability of forests (esp 8.3, 8.4, 8.5) M15 – Forest-environment-climate M12.2 – N2K M16.5 – joint action M1, M2 (advice/ training) to support M20 (EIP network) to support	1(O) As above.		1(O) As above.	1 (O) As above	1 (O/R) As above	2 (O/R) As above	1(O) As above	1/2(R) As above	- As above	1 (R) As above
Crop Production	Reduced Tillage	(+)	N/A Insufficient evidence of mitigation potential										
Crop Production	Zero Tillage	+	M10.1 – AECM M11 – if part of an organic system M1, M2 (advice/ training) to support M20 (EIP network) to support	1(O) As above.	3 (O) To provide evidence to justify rationale for introducing the action and inform decisions about the targeting of the action,	1(O) As above.	1 (O) As above	1 (O/R) As above	2 (O/R) As above	1(O) As above	1/2(R) As above	- As above	1 (R) As above
Crop Production	Leaving Crop Residues on the soil surface	+	M10.1 – AECM M11 – if part of an organic system M1, M2 (advice/ training) to support M20 (EIP network) to support	1(O) As above.	3 (O) To provide evidence to justify rationale for introducing the action and inform decisions about the targeting of the action,	1(O) As above.	1 (O) As above	1 (O/R) As above	2 (O/R) As above	1(O) As above	1/2(R) As above	- As above	1 (R) As above
Crop Production	Ceasing burning of vegetation & crop residues	+	N/A Should be covered under cross-compliance										
Crop Production	Use cover/catch crops and reduce bare fallow	+	M10.1 – AECM M11 – if part of an organic system M1, M2 (advice/ training) to support M20 (EIP network) to support	1(O) As above.	3 (O) To provide evidence to justify rationale for introducing the action and inform decisions about the targeting of the action,	1(O) As above.	1 (O) As above	1 (O/R) As above	2 (O/R) As above	1(O) As above	1/2(R) As above	- As above	1 (R) As above
Livestock Production	Livestock disease management	++	M14 (animal welfare – where net cost to business) M16.2 – development of new products, practices, processes and technologies M1, M2 (advice/ training) to support M20 (EIP network) to support	1(O) As above.	4 (O) To identify diseases which lead to the greatest impairment of livestock performance that are amenable to treatment. Modelling needed to estimate GHG abatement potential.	1(O) To review targeting of action to ensure effectiveness in reducing GHG emissions	1(O) To determine what it would be feasible to support under EAFRD, to target, establish payment rates and determine control criteria	1 (O/R) As above	2 (O/R) As above	1(O) As above	1/2(R) As above	- Systems already in place	
Livestock Production	Use of sexed semen for breeding dairy replacements	+	M16.2 - development of new products, practices, processes and technologies M1, M2 (advice/ training) to support M20 (EIP network) to support	N/A – does not tend to be funded under EAFRD at present	3 (O) To provide evidence to justify rationale for introducing the action and inform decisions about the targeting of the action,	N/A – does not tend to be funded under EAFRD at present	1 (O) To determine what it would be feasible to support under EAFRD – likely mainly to be encouraging use of semen sexing technologies via advice and training	N/A – does not tend to be funded under EAFRD at present	2 (R) To put in place the guidance materials, advice and training, train the advisers and delivery staff.	N/A – does not tend to be funded under EAFRD at present	- Would use existing systems for verifying advice and training provision more widely	N/A – does not tend to be funded under EAFRD at present	- Would use existing systems for monitoring and evaluating advice and training provision more widely
Livestock Production	Breeding low methane emissions in ruminants	+	N/A For 2014-2020										
Livestock Production	Use of feed additives	+	N/A No need for support as benefits business efficiency										
Livestock Production	Optimise feed strategies	+	M1, M2 (advice/ training) to support M20 (EIP network) to support	As above	2-3(O) Research needed on cost-effectiveness in relation to to different farm sizes as well as implications of potential land use change on other environmental priorities.	As above	As above	As above	As above	As above	As above	As above	As above
Nutrient & Soil management	Soil and nutrient management plans	+	M10.1 - AECM M1, M2 (advice/ training) to support M20 (EIP network) to support	1 (O) to inform decisions on how the CMA should be targeted in locations where it is not currently operating	3 (O) To provide evidence to justify rationale for introducing the action and inform decisions about the targeting of the action,	1(O) To assess content of measures and how their use can be extended in a cost-effective manner	1 (O) Development of prescriptions, target areas, payment rates + control criteria	1 (O/R) Revisions to scheme guidance. Possible additional costs for processing applications[1]	2 (O/R) Potential extra time to process applications. New guidance materials and advice. Training for advisers and delivery staff	1(O) Systems would already be in place. Possible extra time for additional control checks	1/2(R) Costs will depend on number of additional checks and controls required	- Systems would already be in place	1 (R) Develop methods / indicators for monitoring new action and incorporate into existing M&E systems/ requirements
Nutrient & Soil management	Use of urease inhibitors and next-generation nitrification inhibitors	+++	N/A For 2014-2020 as food safety issues still to be resolved										

	Improved nitrogen efficiency	+	M10.1 - AECM M1, M2 (advice/ training) to support M20 (EIP network) to support	1 (O) to inform decisions on how the CMA should be targeted in locations where it is not currently operating	3 (O) To provide evidence to justify rationale for introducing the action and inform decisions about the targeting of the action,	1(O) To assess content of measures and how their use can be extended in a cost-effective manner	1 (O) To determine what it would be feasible to support under EAFRD and if more than advice, to develop prescriptions, target areas, payment rates + control criteria	1 (O/R) Revisions to scheme guidance. Possible additional costs for processing applications[1]	2 (O/R) Potential extra time to process applications. New guidance materials and advice. Training for advisers and delivery staff	1(O) Systems would already be in place. Possible extra time for additional control checks	1/2 (O/R) Costs will depend on number of additional checks and controls required For advice and training existing systems can be used	- Systems would already be in place	1 (R) Develop methods / indicators for monitoring new action and incorporate into existing M&E systems/ requirements For advice and training existing systems can be used
	Biological N fixation in rotations and in grass mixes	+	M10.1 – AECM M11 if part of organic system M1, M2 (advice/ training) to support M20 (EIP network) to support	1 (O) As above	3 (O) As above	1 (O) As above	1 (O) As above	1 (O/R) As above	2 (O/R) As above	1 (O) As above	1/2 (O/R) As above	- As above	1 (R) As above
Energy	Carbon auditing tools	+	M10.1 – AECM M4.3 – investments to develop, modernise, adapt agriculture M16.2 – development of new products, practices, processes and technologies M1, M2 (advice/ training) to support M20 (EIP network) to support	1 (O) As above	3 (O) As above	1(O) To assess content of measures and how their use can be extended in a cost-effective manner	1 (O) As above	1 (O/R) Revisions to scheme guidance. Possible additional costs for processing applications[1]	2 (O/R) As above	1(O) Systems would already be in place. Possible extra time for additional control checks	1/2 (O/R) As above	- Systems would already be in place	1 (R) As above
	Increased energy efficiency	++	M4.3 – investments to develop, modernise, adapt agriculture M16.2 – development of new products, practices, processes and technologies M1, M2 (advice/ training) to support M20 (EIP network) to support	1 (O) As above	3 (O) As above	1 (O) As above	1 (O) As above	1 (O/R) As above	2 (O/R) As above	1 (O) As above	1/2 (O/R) As above	- As above	1 (R) As above

[1] Whether or not additional staff costs are required for processing applications will depend on the design on the scheme – i.e. whether it is accessible to all or discretionary. If open to all, then applications may increase. If the scheme is discretionary then any increase in applications for this management action is likely to be cancelled out by reduction in another.

Annex 5: Use of CAP policy tools to improve uptake of climate mitigation actions

Climate policy within the CAP

The CAP is an important economic driver for farming decisions across the EU and has the potential to advance climate policy by building climate-related objectives into the overall pattern of support through its measures and associated obligations. Although the level of EU competence for forestry is much more limited than it is for agriculture, the CAP remains the only source of EU funding to provide incentives for environmental afforestation, establishment of agroforestry systems and sustainable forest management.

The CAP is structured as two 'Pillars':

- Pillar 1 which is funded by the European Agricultural Guarantee Fund (EAGF) and mainly provides **direct payments** to farmers per hectare of land farmed; and
- Pillar 2, co-financed by the European Agricultural Fund for Rural Development (EAFRD) supports Member States' and regions' **Rural Development Programmes** (RDPs) with a wide range of measures to address environmental, social, and economic priorities in the agricultural and forestry sectors, and rural areas Member States and regions are given a very large degree of flexibility in designing their seven-year RDPs to meet their specific needs. There were 88 RDPs for EU-27 in 2007-13 but for EU-28 in the 2014-20 period there will be 118 in total.

The CAP for 2014 to 2020 has three over-arching objectives of viable food production, sustainable management of natural resources and climate action, and balanced territorial development.

It is important to emphasise that the CAP measures in use today have been introduced and refined over a series of incremental reforms since the policy was first introduced in 1962. Several of the measures most relevant to the climate actions identified in this study have been implemented in one form or another by Member States for a very long time, in some cases for many decades. For example, support for afforestation and for agri-environment land management contracts date from the 1980s, and the origins of cross-compliance date from requirements for 'good farming practice' introduced in the 1990s.

CAP programming now follows the seven-year cycle of the Multiannual Financial Framework (MFF). Climate mainstreaming was introduced during the 2007-13 period and has been taken a step further for 2014 to 2020, with a commitment that 20 per cent of expenditure should be devoted to the pursuit of climate objectives. This has significance for the CAP, which has a budget that accounts for about 37 per cent of the MFF.

The implementation of the CAP measures most relevant to climate actions is summarised here for the programming periods 2007-13 and 2014-20, covering cross compliance, Pillar 1 greening and Member States' RDPs.

Distinguishing climate actions within broader environmental measures within the CAP

The way in which CAP measures have been used to deliver environmental outcomes has evolved over time, with a focus on climate mitigation being a more recent priority. Although climate may feature as an objective of specific measures within the CAP, the available literature, data and specific evaluation reports tend to report on the implementation of measures with multiple objectives, not just climate. In addition, Rural Development Programmes tend to have a strong path dependency between programming periods, in the sense that the content and focus of programmes often evolves rather than be subject to major changes. This means that where measures have been implemented for other environmental reasons, e.g. biodiversity or water or soil quality, but where these could also have climate mitigation benefits, they may either simply continue to be implemented without necessarily labelling them as being beneficial for reducing greenhouse gas emissions or in some cases the 'climate' objective is added to the measure. Furthermore, the way in which the measures are designed for operation on the ground does not necessarily correlate directly with the actions identified under Task 1.1. For example 'organic farming' or 'integrated farm management' is often cited as a key measure for climate mitigation, which could cover a number of the specific climate actions identified for this study.

Where land managers have a choice of options from, for example, a list of greening requirements or a 'menu-based' agri-environment scheme, then data on 'uptake' of climate actions at a farm level will rarely be available, because of the way in which Member States' CAP monitoring requirements are defined. Data is available at Member State/regional level in terms of commitments and uptake of RDP expenditure per RDP *measure* for the 2007-13 period, and of expenditure commitments for the 2014-20 period. Where detailed climate action relevant data is not available we have used a higher level of aggregation of climate actions within categories that broadly 'read across' to the way in which CAP policy tools and measures are defined.

The limited scope of available information on climate specific actions within the CAP means that the achievable level of detail will not be the same for all actions, for all parts of the CAP or for all Member States. On the whole, there is better documentation and analysis of RDPs at Member State and regional level is than there is for Pillar 1 measures, especially for the 2007-13 period. However, even this RDP data is not disaggregated to the level of implementation within measures (e.g. climate actions within an agri-environment scheme or investment support programme).

Cross-compliance standards with benefits for climate mitigation

Farmers receiving direct payments under Pillar 1 and area-based payments under Pillar 2 must comply with cross-compliance requirements (SMRs and GAEC standards) across the whole farm holding, or risk loss of part of their CAP payments. Additionally, recipients of EAFRD agri-environment-climate payments are required to comply with farm level requirements on the use of fertilisers and plant protection products, which Member States define in their RDPs[5].

The framework for GAEC standards changed from 2015, as shown in Figure 1. Compared to the 2007-13 period the number of standards has been reduced and all standards are compulsory for Member State to define.

Figure 1 Framework of issues and standards for GAEC cross-compliance until 2014 and from 2015

Issue	2007-2014		2015-2020	Link between climate objectives and 2015-20 standards
	Compulsory standards	Optional standards	Compulsory requirements and standards	

[5] Article 28(3) of Regulation 1305/2013

Soil	Minimum soil cover	Retain terraces	**GAEC 4** Minimum soil cover	Protection of carbon stores and sequestration potential in soils
	Minimum land management reflecting site-specific conditions		**GAEC 5** Minimum land management reflecting site specific conditions to limit erosion	Protection of carbon stores and sequestration potential in soils
	Arable stubble management	Standards for crop rotations	**GAEC 6** Maintenance of soil organic matter level through appropriate practices including ban on burning arable stubble, except for plant health reasons (1)	Reduced GHG emissions from fires
		Appropriate machinery use (maintain soil structure)		
Landscape	Retention of landscape features, including, where appropriate, hedges, ponds, ditches trees in line, in group or isolated and field margins	Minimum livestock stocking rates or/and appropriate regimes *Establishment and/or retention of habitats*	**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 and, as an option, measures for avoiding invasive plant species.	Protection of carbon stores and sequestration potential in woody vegetation, wetlands and soils
	Avoiding the encroachment of unwanted vegetation on agricultural land	Prohibition of the grubbing up of olive trees		
	Protection of permanent pastures	Maintenance of olive groves and vines in good vegetative condition	[Protection of permanent pastures in 2015 and 2016, only]	Protection of carbon stores and sequestration potential in permanent grasslands and soils
Water	Establishment of buffer strips along water courses		**GAEC 1** Establishment of buffer strips along water courses (2)	Protection of carbon stores and sequestration potential in permanent grasslands and soils
	Where use of water for irrigation is subject to authorisation, compliance with authorisation procedures		**GAEC 2** Where use of water for irrigation is subject to authorisation, compliance with authorisation procedures	Reduced risk of loss of carbon stores and sequestration potential as a result of wetlands drying out
			GAEC 3 Protection of ground water against pollution: prohibition of direct discharge into groundwater and measures to prevent	Reduced risk of loss of carbon stores and sequestration potential as a result of pollution damage to wetlands

			indirect pollution of groundwater through discharge on the ground and percolation through the soil of dangerous substances, as listed in the Annex to Directive 80/68/EEC in its version in force on the last day of its validity, as far as it relates to agricultural activity	
Notes: (1) The requirement can be limited to a general ban on burning arable stubble, but a Member State may decide to prescribe further requirements. (2) The GAEC buffer strips must respect, both within and outside NVZ, at least the requirements relating to the conditions for land application of fertiliser near watercourses. Source: Compiled using Regulation (EC) No 73/2009, Annex III and Regulation (EU) No 1306/2013, Annex II.				

Member States must define their GAEC standards taking into account the specific characteristics of the areas concerned, including soil and climactic conditions, existing farming systems, land use, crop rotation, farming practices and farm structures. The 2015 standards most relevant to climate mitigation are those for soil and for the retention of landscape features, which are relevant to several climate mitigation actions identified under this study as having potential to reduce GHG emissions on agricultural land in the EU. For example:

GAEC standard	Requirements	Relevant to climate mitigation actions
4	**Minimum soil cover**	• Use cover/catch crops and reduce bare fallow • Biological N fixation in rotations and in grass mixes
5	**Site specific land management to limit erosion**	• Use cover/catch crops and reduce bare fallow • Conversion of arable land to grassland
6	**Maintenance of soil organic matter, including ban on burning arable stubble**	• Ceasing burning crop residues • Returning crop residues to the soil
7	**Retention of landscape features:**	
	Hedges	• Woodland management (including hedgerows and single trees)
	Ponds	• Conservation of existing peatland and wetland
	Trees in lines, groups or isolated	• Woodland management (including hedgerows and single trees)
	Field margins	• Conversion of arable land to grassland to sequester carbon in the soil

The extent of the actual benefit to climate mitigation depends on how rigorously Member States define the standards and the extent to which farmers comply. The 'policy reach' of GAEC standards is limited by farmers' perception of the costs of compliance, the risk of the detection of non-compliance and the likely scale of the financial penalties in the year in which the breach is detected.

Member States' definition of GAEC standards 2007-14 and for 2015

The 2007-13 GAEC framework (which was extended for use until the end of 2014) had both optional and compulsory standards, which meant that implementation varied across the EU, not just in the way that the same standards was defined in different places, but in which optional standards Member States chose to implement, as shown in Figure 2. This partly reflected differences in land management systems, for example olive groves are largely confined to southern Europe.

Figure 2: Use of 2007-14 GAEC standards by Member States[6]

[6] 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

	Soil erosion			Soil organic matter			Soil structure		Minimum level of maintenance								Protection and management of water				Art. 6(2) Reg. 73/2009
MS	Minimum soil cover	Minimum land management	Retain terraces	Standards for crop rotations	Arable stubble management	Other standards	Appropriate machinery use	Other standards	Minimum livestock stocking rates/regimes	Protection of permanent pasture	Retention of landscape features	Avoiding the encroachment of unwanted vegetation	Maintenance of olive groves/vines	Establishment and/or retention of habitats	Prohibition of the grubbing up of olive trees	Other standards	Establishment of buffer strips along water courses	Compliance with authorisation procedures	Protection of ground water against pollution	Other standards	Permanent pasture
AT	x	x	x	x	x		x		x	x	x	x	x				x	x	x		x
BE-F				x	x		x		x	x	x	x		x			x	x			x
BE-W	x	x			x					x	x	x					x	x	x		x
BG	x	x	x	x	x		x		x	x	x	x					x	x			x
CY	x	x	x	x	x		x			x	x	x			x		x	x	x		x
CZ	x	x	x	x	x		x	x	x	x	x	x					x	x	x		x
DE	x	x	x	x	x				x	x	x	x					x	x	x		x
DK	x	x			x					x	x	x					x	x	x		
EE	x	x		x	x		x		x	x	x	x		x			x	x	x		x
EL	x	x	x	x	x		x		x	x	x	x	x				x	x	x		x
ES	x	x	x		x		x		x	x	x	x	x	x	x		x	x			x
FI	x	x		x	x		x		x	x	x	x					x	x	x		x
FR	x	x		x					x	x	x	x	x		x		x	x	x		x
HR	x	x		x	x		x			x	x	x	x				x	x	x		
HU	x			x							x								x		
IE	x	x		x	x	x	x	x	x	x	x	x				x	x			x	x
IT	x	x	x	x	x		x		x	x	x	x	x		x		x	x	x		x
LT	x	x		x	x				x	x	x	x					x	x	x		x
LU	x	x	x	x	x	x			x	x	x	x		x			x		x		x
LV	x	x			x		x		x	x	x	x					x	x	x		x
MT	x	x	x	x	x		x			x	x	x	x	x	x		x	x	x		x
NL	x	x		x	x				x	x	x	x					x	x	x		x
PL	x	x		x	x		x		x	x	x	x		x			x	x	x		x
PT	x	x	x	x	x		x		x	x	x	x	x		x		x	x	x		x
RO	x	x	x	x	x		x		x	x	x	x					x	x	x		x
SE	x	x			x				x	x	x	x		x			x	x	x		x
SI	x	x	x	x	x		x		x	x	x	x	x				x	x	x		x
SK	x	x	x	x	x		x		x	x	x	x					x	x	x		
UK-E	x	x		x	x		x		x	x	x	x		x			x	x	x		x
UK-NI	x	x		x	x		x		x	x	x	x		x			x	x	x		x
UK-S	x	x		x	x		x		x	x	x	x					x	x	x		x
UK-W	x	x		x	x		x		x	x	x	x					x	x			x

Source: Mars Wiki JRC (2014) downloaded on 4 December 2014 https://marswiki.jrc.ec.europa.eu/gaec/appl.php

From 2015 Member States must implement all seven GAEC standards (see Figure 1, last column). The following analysis identifies climate mitigation actions (relevant to those identified in this study) that were defined as part of GAEC standards by Member States in 2014 and 2015[7].

Minimum soil cover and site specific management to limit soil erosion

The soil cover and management requirements apply in practice mainly to arable land and the definitions tend to be linked to the current use of the land and/or its physical characteristics such as slope, or to be a requirement to provide cover on a certain proportion of the arable land.

In 2014 green cover was required on arable land not used for production in four Member States (AT; DK; FI; HR; LT); in the Netherlands it was for the months May to August after a maize crop. Sloping land was the defining criterion for winter cover in five Member States (BE-W; CZ; LV; MT; SK) and for green cover in two Mediterranean Member States (CY; EL). Winter cover requirements applied specifically to land at risk of soil erosion in seven Member States (DE; ES; IT; LU; PL; SE; UK-EN). One Member State specified that the soil cover should be either plant residue or mulch (SI). In Bulgaria soil cover was required on at least 30 per cent of arable land over five hectares (including land in rotation). In Romania winter cover is required on at least 20 per cent of the arable area and in Estonia on at least 30 per cent of agricultural land in specific areas. In France winter cover is required on arable land that is not in rotation and where one crop constitutes more than 95 per cent of total area. In five Member States the winter cover requirements applied to all land (HU; IE; PT; UK-NI, UK-SC)

In 2015 most of the 13 Member States allowed the minimum soil cover under GAEC 4 to be stubble or green cover, but for groundwater areas in Finland green cover is compulsory and where this cover is grass up to 20 per cent of the seed mix can be N-fixing plants. In the Netherlands the previous requirement for green cover after maize crops has been extended to apply after cereal crops too. Sloping land continued to be the defining criterion for soil cover in Latvia, Malta and Slovakia, while Bulgaria and Estonia continued to define the soil cover requirement in terms of proportion (30 per cent of the crop rotation area in Bulgaria, 30 per cent of all land in Estonia). Three of the 13 Member States limited the soil cover requirement to defined geographical areas (EE, MT and SE).

Under GAEC 5 in 2015 the 13 Member States defined a wide range of climate relevant actions that farmers may use to limit soil erosion, mostly for arable land but also for permanent crops (Bulgaria) and pastureland (Ireland and the UK). Several Member States (BG, EE, SE, SI and UK) include green cover or arable conversion to grassland (e.g. between rows of permanent crops, or as buffers across hillsides) among the options. Finland requires temporary fallow in the form of a 1m wide uncultivated headland alongside water courses/bodies.

Ban on burning arable stubble and practices to maintain soil organic matter

In 2014 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, especially in the Mediterranean, put additional requirements in place related to ploughing-in stubbles: where appropriate in BG and CY, and in special circumstances in EL; IT; MT and the UK. Exceptions to the arable stubble management requirements were allowed, and these related to plant health (burning helps to destroy plant pests and diseases) in eight Member States (AT; HR; CY; DK; FI; LT; MT; ES); to weather in Austria; where straw is used for soil cover in DK and LU (during March to September) or is waste in Lithuania. Some Member States do not define the exceptions but simply require farmer 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.

[7] Data for 2014 standards is for all Member States (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
Data for 2015 standards is for 13 Member States: BG, EE, FI, HU, IE, LT, LV, MT, NL, SE, SI, SK and UK (except Northern Ireland) Source: Mars Wiki JRC (2015) downloaded on 27 July 2015 from https://marswiki.jrc.ec.europa.eu/gaec/index.php

In 2015 all 13 Member States reviewed here have banned burning stubble on arable land and several also banned burning of crop residues (EE, HU, IE, LT, MT, NL, SI, SK and UK(W)) often with exemptions where burning was required for plant health reasons (Sweden has a specific exemption for burning in preparation for sowing oilseed rape, no more than once every 3 years). Malta also requires ploughing-in of stubbles/residues where possible. Five of the 13 Member States also ban burning of grasslands (EE, HU, LT, LV, SK), and although the UK permits burning of heathland and rough grassland[8] farmers are required when doing so to observe specific legal requirements (E and W) or codes of practice (Scotland). Four of the 13 Member States also have specific requirements for crop rotations in certain, defined circumstances, with the aim of maintaining soil organic matter (EE, HU, MT, SI and SK).

Retention of landscape features (2015)

Member States can define appropriate landscape features for the GAEC 7 standard and require farmers to retain these (although there is no obligation to actively maintain them through appropriate management). For 2015 there is an indicative list of nine standards (of which five are relevant to climate mitigation actions to protect existing stores of carbon in woody vegetation or wetland) but Member States can define additional standards if they wish.

This standard gained additional significance in 2015 because Member States could, if they wished, make ‘dual use’ of some or all of landscape features that they required farmers to retain under the GAEC standard by also defining these as one of the EFA options that farmers could use to meet their EFA requirements under the greening payment.

The choice of landscape features made by the 13 Member States for GAEC 7 standards in 2015 are shown in Figure 3, which indicates if the GAEC standard has also been used as an EFA option. In some Member States, where a type of landscape feature is not part of the main GAEC standard, additional standards have been defined to apply to specific categories of that type feature. Often these refer to existing national protective designations (for example isolated trees in Estonia, Latvia and Lithuania, and habitats protected for their biological interest in England). In Malta the extra standards include vegetated slopes separating terraced fields and habitat patches acting as field margins.

[8] usually for the purpose of encouraging new, young growth that is more palatable to livestock

Figure 3 Landscape features chosen for GAEC 7 by Member State[9]

MS	Hedges	Trees			Field margins	Ponds	Other standards relevant to mitigation
		isolated	in line	in groups			
BG					EFA		
EE	EFA		EFA	EFA			wooded strips; protected trees; and springs
FI							designated natural monuments <0.2ha
HU		EFA		EFA		EFA	
IE	EFA		EFA				designated habitats (created with RDP support)
LT							protected trees and bushes
LV							protected trees and lines of trees
MT							vegetated slopes and habitat patches
NL							
SE							
SI							
SK		EFA	EFA	EFA	EFA		
UK (E)	EFA						designated Sites of Special Scientific Interest
UK (S)							
UK(W)							

Key:

	defined for GAEC 7
EFA	GAEC 7 definition also used for EFA
	not defined for GAEC 7

Greening payment implementation with benefits for climate mitigation

Member States must use 30 per cent of their national ceilings for direct payments to grant an annual payment, on top of the basic payment, for compulsory practices to be followed by farmers addressing, as a priority, both climate and environment policy goals. Those practices should take the form of simple, generalised, non-contractual and annual actions that go beyond cross compliance and are linked to agriculture. The three 'greening' measures are: crop diversification, the maintenance of permanent pasture and Ecological Focus areas (on five per cent of eligible arable area). Not all these 'greening measures are designed to deliver climate benefits, however. The two that have the most potential to deliver climate benefits, alongside other environmental benefits include the maintenance of permanent grassland and ecological focus areas. Nonetheless, the crop diversification measure could have an indirect climate mitigation benefit in the sense that, if it were to increase the area of land under leguminous crops (which fix nitrogen in the soil) this may reduce the levels of mineral nitrogen fertiliser required and the crops themselves may displace imported protein-rich animal feed and lead to a small reduction in any climate impacts associated with this.

Actual benefits will depend on the choices Member States have made to implement the measures, given the significant flexibilities available, the area that is subject to the greening requirements (once exemption criteria have been taken into account) as well as what changes to farmland management ensues on the ground.

[9] Source: Mars Wiki JRC (2015) downloaded on 27 July 2015 from https://marswiki.jrc.ec.europa.eu/gaec/index.php

Climate mitigation potential of the EFA measure

Member States have a choice of 10 standard elements that they can make available to farmers to fulfil their EFA obligations on arable land. One of these (strips along forest edges) can be subdivided into two – strips without production and strips with production. Member States can also choose which of a series of nine landscape features are eligible to count towards the EFA obligation.

Many of these elements have the potential to be beneficial for climate mitigation and are similar to the climate mitigation actions identified as having most potential to reduce GHG emissions on agricultural land in the EU under this study. For example:

EFA element	Relevant to climate mitigation actions
Land lying fallow	• Zero tillage
Terraces	-
Landscape features:	
Hedges or wooded strips	• Woodland creation • Woodland management (including hedgerows and single trees)
Isolated trees	• Woodland creation • Woodland management (including hedgerows and single trees)
Trees in a line	• Woodland creation • Woodland management (including hedgerows and single trees)
Trees in groups – field copses	• Woodland creation • Woodland management (including hedgerows and single trees)
Field margins	• Conversion of arable land to grassland to sequester carbon in the soil
Ponds	-
Ditches	-
Traditional Stone Walls	-
Other landscape features	-
Buffer Strips	• Conversion of arable land to grassland to sequester carbon in the soil
Hectares of agroforestry	• Agroforestry
Strips of eligible hectares along forest edges:	
With production	-
Without production	• Conversion of arable land to grassland to sequester carbon in the soil
Areas with short rotation coppice	• Short rotation forestry
Afforested areas	• Woodland creation • Woodland management (including hedgerows and single trees)
Areas with catch crops or green cover	• Use cover/catch crops and reduce bare fallow • Biological N fixation in rotations and in grass mixes
Areas with nitrogen fixing crops	• Biological N fixation in rotations and in grass mixes

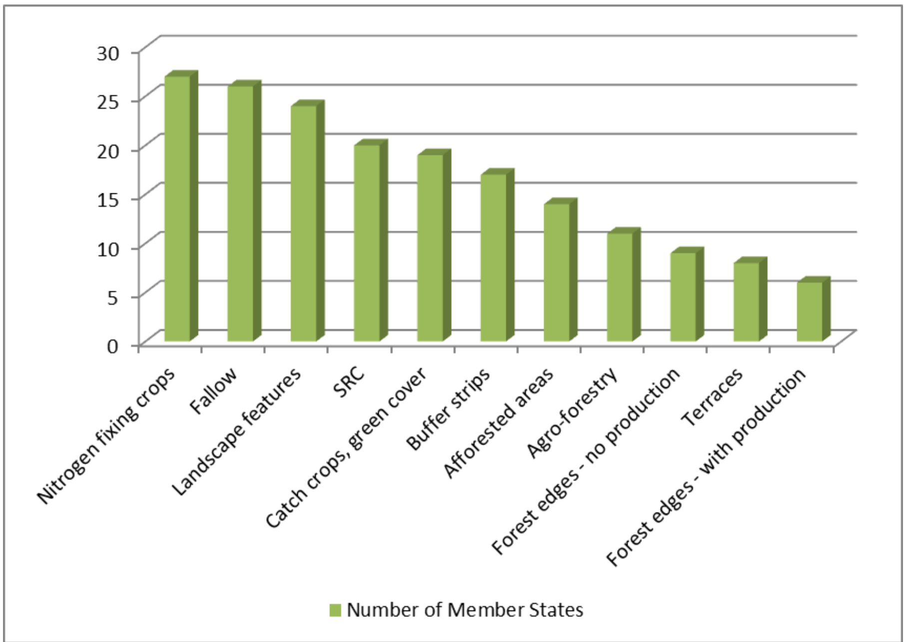
The most popular EFA elements identified above as being beneficial for climate mitigation, chosen by more than two-thirds of Member States are areas with nitrogen fixing crops (27 MSs – all except Denmark), followed by landscape features (24 – all but Spain, Cyprus, Lithuania and Slovenia); areas with short rotation coppice (20 – all but Greece, Spain, Cyprus, Latvia, Lithuania, Malta, Portugal and Slovenia, as well as England and Scotland in the UK); and areas with catch crops or green cover (19 – all but Estonia, Greece, Spain, Italy, Cyprus, Lithuania, Malta, Portugal, Finland as well as Northern Ireland and Wales in the UK) – see Figure 4 and a breakdown by Member State in Table 32.

There is a degree of flexibility in relation to the rules that are put in place to inform how some of these elements are to be implemented in practice. For example, for nitrogen fixing crops, catch crops/green cover and short rotation coppice 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 fertilisers 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.

For example, for the catch crops/green cover option, a range of start and end dates for the sowing period has been identified. The start dates range from 15 May in Slovakia (with Denmark permitting undersowing from 1 January) to 1 September in Bulgaria. The end dates range from 15 June in Sweden (31 May in Denmark for undersowing) and 1 October, with 15 October the end date in Romania for green cover. In terms of permitting fertilisers to be used on catch crops and green cover, it appears that all but two Member States (Germany and Belgium-Wallonia) will allow them. In relation to nitrogen-fixing crops, their climate impacts will be context dependent and depend heavily on the way in which it is managed. In particular it is important to avoid sudden emissions of nitrates from the soil when ploughed. However, very few Member States appear to have put in place post-harvest requirements to avoid this problem, such as the need to follow the crop with either a green cover crop or a crop that requires nitrogen (both Germany and Spain have included such requirements). No information is available on which countries have permitted nitrogen fertilisers on nitrogen fixing crops, but information from a selection of nine Member States (Hart, 2015) suggests that most Member States have allowed fertiliser application on these crops within EFAs.

A number of the measures (e.g. agroforestry and afforestation) permit only the inclusion of areas that have been approved for funding under rural development programmes (previous or current). This means that although these actions will have some climate mitigation benefits, they should not be double counted, as the benefit will already have been achieved via the rural development measure. The same is true where the landscape features protected under cross-compliance have also been identified as eligible to fulfil the EFA obligation (see Table 33).

Figure 4: EFA elements chosen by Member States as eligible to qualify as EFA



Source: European Commission, 2015

Table 32: Detail of which EFA elements Member States have chosen as eligible to qualify as EFA

MS	Fallow	Terraces	Landscape Features	Buffer Strips	Agroforestry	Forest edges - with production	Forest edges - without production	SRC	Afforested areas	Catch crops etc	N fixing crops	Total EFA elements by MS (max=11)
AT	√		√					√		√	√	5
BE - Fl	√		√	√	√	√	√	√	√	√	√	10
BE - Wa	√		√	√	√		√	√		√	√	8
BG	√	√	√	√			√	√		√	√	8
HR	√		√	√			√	√		√	√	7
CY	√			√	√				√		√	5
CZ	√	√	√					√	√	√	√	7
DE	√	√	√	√	√		√	√	√	√	√	10
DK	√		√	√				√		√		4
EE	√		√					√			√	4
EL	√		√	√							√	4
ES	√				√				√		√	4
FI	√		√					√			√	4
FR	√	√	√	√	√	√	√	√	√	√	√	11
HU	√	√	√	√	√	√	√	√	√	√	√	11
IE	√		√	√				√	√	√	√	7
IT	√	√	√	√	√	√	√	√	√		√	10
LT	√										√	2
LU	√		√	√	√	√	√	√	√	√	√	10
LV	√		√	√						√	√	5
MT	√		√								√	3
NL			√					√		√	√	4
PL	√		√	√		√	√	√	√	√	√	9
PT	√		√		√				√		√	5
RO		√	√	√				√	√	√	√	7
SE	√		√		√			√		√	√	6
SI	√									√	√	3
SK	√	√	√	√				√		√	√	7
UK - EN	√		√	√						√	√	5
UK - NI	√		√		√			√	√		√	6

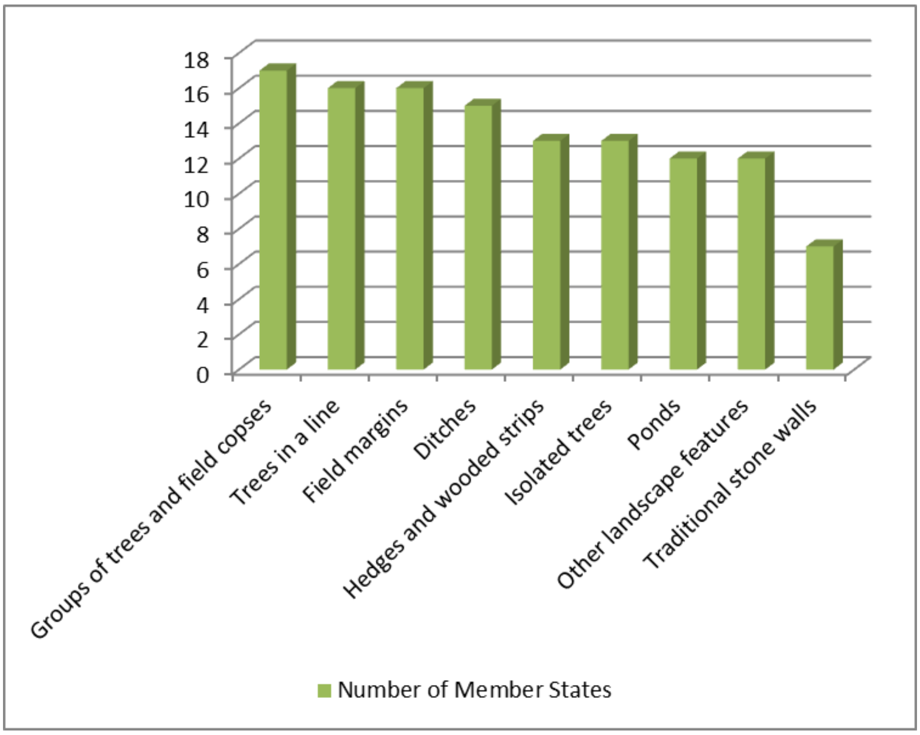
UK - SC	√		√	√						√	√	5
UK - W	√		√		√			√	√		√	6
EU 28*	**30**	**8**	**27**	**19**	**13**	**6**	**10**	**22**	**15**	**21**	**31**	

* The total number is 32, including the UK and BE regions

NB: Greyed out columns are those elements that are not associated with the key climate mitigation actions identified for this study.

In terms of the types of landscape features permissible to count towards the EFA obligation, amongst the most popular are those that could have climate mitigation benefits (group of trees and field copse, trees in a line). The relative popularity of the different landscape features is shown in Figure 5.

Figure 5: Types of landscape features permitted within EFAs for the EU-28



Source: European Commission, 2015

The different landscape features chosen by Member States are set out in Table 33. This also identifies whether or not the landscape features that can count towards the EFA are the same as those protected under cross-compliance (e.g. GAEC7, SMR2, SMR3) or are different to those protected under cross-compliance, either different features included, or different requirements (e.g. width, height etc) are stipulated.

Four Member States chose not to include landscape features within their EFA (Spain, Cyprus, Lithuania and Slovenia). In terms of those features that are associated with the climate mitigation actions identified as a priority for this study these are not chosen by a further four countries: Austria, Denmark, Finland and Portugal.

Table 33: Landscape features chosen by Member State

GAEC7/SMR2/SMR3: where Member States have chosen the same features as covered by cross-compliance to count towards the EFA obligation

A45: where Member States have used the additional options available to them under Article 45 of the delegated regulation EU 639/2014 to extend the types of landscape features eligible for EFA beyond those covered by cross-compliance.

MS	Hedges or wooded strips	Isolated trees	Trees in line	Trees in groups - field copses	Field margins	Ponds	Ditches	Traditional stone walls	Other landscape features	TOTAL landscape features/MS
AT						GAEC7	GAEC7	GAEC7	GAEC7	4
BE - Fl	A45			A45	A45	A45	A45			5
BE - Wa	GAEC7	GAEC7	GAEC7	GAEC7	GAEC7	GAEC7	GAEC7			7
BG	A45	A45	A45	A45	A45 / GAEC7	A45	A45			7
HR	GAEC7	GAEC7	GAEC7	GAEC7		GAEC7	GAEC7	GAEC7		7
CY										0
CZ		GAEC7	GAEC7	GAEC7	A45		GAEC7		GAEC7	6
DE	GAEC7	GAEC7	GAEC7	GAEC7	A45/ GAEC7		GAEC7	GAEC7	GAEC7	8
DK						GAEC7			GAEC7	2
EE	GAEC7		GAEC7	GAEC7			GAEC7	GAEC7		5
EL			A45/ GAEC7	A45			A45			3
ES										0
FI									GAEC7	1
FR	A45	A45	A45	A45	A45	A45	A45	A45		8
HU	A45	A45/ GAEC7	A45	GAEC7	A45	GAEC7	A45		GAEC7	8
IE	GAEC7		GAEC7	A45			GAEC7		GAEC7	5
IT	GAEC7/ SMR2/ SMR3	GAEC7/ SMR2/ SMR3	GAEC7/ SMR2/ SMR3	A45	A45	GAEC7/ SMR2/ SMR3	GAEC7/ SMR2/ SMR3	GAEC7/ SMR2/ SMR3	Y but no details	9
LT										0
LU	SMR2/3	SMR2/3	SMR2/3	SMR2/3	A45	SMR2/3				6
LV				A45	A45	A45			GAEC7	4
MT		A45	A45	A45	A45				GAEC7/ SMR3	5
NL					A45					1
PL	A45	A45/ GAEC7	A45	A45	A45	A45/ GAEC7	A45/ GAEC7			7

PT									GAEC7/ SMR2/ SMR3	1
RO	A45	A45	A45	A45	A45	A45	A45			7
SE					A45					1
SI										0
SK		GAEC7/ SMR2/ SMR3	GAEC7/ SMR2/ SMR3	GAEC7/ SMR2/ SMR3	GAEC7/ SMR3					4
UK - EN	GAEC7									1
UK - NI	GAEC7						GAEC7	GAEC7	GAEC7	4
UK - SC					A45					1
UK - W	A45							A45		2
EU-28*	**16**	**13**	**16**	**18**	**15**	**13**	**16**	**8**	**10**	

* The total number is 32, including the UK and BE regions

NB: Greyed out columns are those elements that are not associated with the key climate mitigation actions identified for this study.

Climate mitigation potential of the 'maintenance of permanent grassland' measure

There are two elements to the greening measure for the maintenance of permanent pasture, each of which is discussed below in terms of their climate mitigation potential.

Maintaining the ratio of permanent grassland to UAA

The first requirement is that Member States must 'ensure that the ratio of the land under permanent grassland in relation to the total agricultural area declared by the farmer…does not decrease by more than 5% compared to a reference ratio to be established by Member States in 2015' (Article 31(2)). The percentage change in permanent pasture may be calculated at national, regional or appropriate sub-regional level. The objective of the measure is defined in recital 42 of Regulation (EU) 1307/2013 as 'to ensure environmental benefits, in particular carbon sequestration'. The same requirement was in place under cross-compliance previously, although the percentage decline permitted was up to 10%.

Almost all Member States (23) have chosen the most flexible route for maintaining the ratio of permanent grassland by applying it at the national level. Belgium, France, Germany and the UK are the only countries to implement this rule at the regional level. Maintaining the ratio of permanent grassland at the regional level should improve the chances of slowing the rate of decline of permanent grassland in those regions where it is most at risk, whereas there is a risk that where the ration is maintained nationally, this can mask significant declines in some areas. The rate of decline will also be affected by the nature of the authorisation systems put in place to determine when permanent grassland can be converted. For example, Germany has put in place a permitting system for all farmers wishing to convert any permanent grassland, with a requirement that any declines must be compensated by increases in permanent grassland elsewhere, whereas England (UK) does not take action until the five per cent threshold is reached (Hart and Radley, 2015).

Climate mitigation potential of designation of environmentally sensitive permanent grassland (ESPG)

The protection of environmentally sensitive permanent grassland (ESPG) is the second element of the 'maintenance of permanent grassland' greening measure[10] and has the greatest potential to address climate mitigation objectives.

This measure requires Member States to designate permanent grasslands which are environmentally sensitive in areas covered by the birds and habitats Directives, including in peat and wetlands situated in these areas, and which need strict protection in order to meet the objectives of those Directives. Member States also have the option to delineate further environmentally sensitive areas not covered by the Habitats Directive (Article 45 of Regulation (EU) 1307/2013). Where land is designated, there is a ban on ploughing and conversion of permanent grassland within those areas. New areas of ESPG can be designated each year.

The objective for the protection of 'environmentally sensitive permanent grassland' is to protect species, land of high nature value, protect against soil erosion and protect water quality (Article 41 of Regulation (EU) 639/2014). However, carbon sequestration will be another important outcome of a ban on ploughing, particularly those on soils with high organic matter content (such as peatlands and wetlands).

Delegated Regulation 639/2014 sets out the criteria for designating environmentally sensitive permanent grassland outside Natura 2000 areas, which include the following types of grassland relevant for climate mitigation:

- covering organic soils with a high percentage of organic carbon, such as peat land or wetlands;
- Covering soils with a high risk of erosion;
- Being located in a sensitive area designated within the river basin management plans pursuant to Directive 2000/60/C.

ESPG within Natura 2000 areas

The proportion of land within Natura 2000 areas that has been designated as environmentally sensitive varies significantly between Member States, from as little as one per cent in Estonia and Portugal to 100 per cent in ten Member States plus three of the UK regions (England, Northern Ireland and Wales). The figures for all countries are set out in Table 34.

Information on the criteria used to determine the proportion of ESPG within Natura 2000 areas to designate is not in the public domain. However, any cessation of ploughing of grassland will prevent the release of carbon into the atmosphere and help sequester carbon over a period of time and the impact will be even more significant where the ESPG covers peatland and wetlands.

[10] The other element is the requirement to 'ensure that the ratio of the land under permanent grassland in relation to the total agricultural area declared by the farmer…does not decrease by more than 5% compared to a reference ratio to be established by Member States in 2015' (Article 31(2)) – operated at national, regional or local level.

Table 34: Area and proportion of permanent grassland in Natura 2000 areas designated as environmentally sensitive by Member States.

	Total area of permanent grassland in Natura 2000 (ha)	Total area of designated sensitive grassland in Natura 2000 (ha)	% ESPG in Natura 2000 (per MS or region)
BG	426,348.00	426,348.00	100%
CZ	131,914.99	131,914.99	100%
EL	489,922.99	489,922.99	100%
ES	1,914,265.44	1,914,265.44	100%
IT	869,545.00	869,545.00	100%
HU	499,691.51	499,691.51	100%
NL	51,451.00	51,451.00	100%
SK	149,651.33	149,651.33	100%
FI	2,700.00	2,700.00	100%
SE	45,595.00	45,595.00	100%
UK - E	304,969.00	304,969.00	100%
UK - W	111,330.00	111,330.00	100%
UK - NI	37,338.26	37,238.77	100%
HR	44,101.64	35,227.97	80%
CY	776.68	557.83	72%
DE	958,000.00	615,000.00	64%
FR	1,760,000.00	1,111,000.00	63%
BE - Fl	24,586.00	12,188.00	50%
LT	68,880.54	29,135.51	42%
PL	622,927.00	260,715.00	42%
UK - S	812,178.00	332,702.00	41%
BE - Wa	25,850.00	9,050.00	35%
SL	73,909.00	19,400.00	26%
LU	8,573.00	2,121.00	25%
DK	52,000.00	10,500.00	20%
AT	269,414.00	15,276.00	6%
LV	62,634.00	1,797.00	3%
IE	32,933.22	613.63	2%
PT	284,049.59	1,726.68	1%
EE	26,000.00	130.00	1%
MT	No permanent grassland	No permanent grassland	
RO	No information	No information	
Total	**10,161,535.19**	**7,491,763.65**	**74%**

Source: European Commission (2015)

ESPG designated outside Natura 2000 areas

Only four countries have decided to designate grassland outside Natura 2000 areas in 2015: Czech Republic, Latvia, Luxemburg and Wales (UK). The areas of additional permanent grassland designated are set out in Table 35.

Table 35: Area of ESPG designated outside Natura 2000 areas in 2015

	Total area of designated sensitive grassland outside Natura 2000 (hectares
CZ	257,767.56
LV	5,739.00
LU	3,904.00
UK - W	53,718.00
Total	**321,128.56**

Source: European Commission, 2015

Luxembourg has designated permanent grasslands that are protected habitats and permanent grassland in flood zones defined under national legislation (Le Gouvernement du Grand-Duché de Luxembourg, 2015). The additional permanent grassland designated by Wales comprises land protected under national nature conservation legislation (biological Sites of Special Scientific interest (SSSI) which are not part of the Natura 2000 network. Ploughing will only be permitted in these SSSI areas if it is necessary for protection of the habitat, and will require written consent. (Welsh Government, 2015). In the Czech Republic ESPG outside Natura 2000 areas consists of a number of different areas of permanent grassland, the most significant from a climate perspective are: permanent grassland at risk of soil erosion and permanent grassland on peat soils, such as wet meadows and peat meadows (Hart and Radley, forthcoming). No information has been found on the ESPG designated in Latvia.

Voluntary coupled support with indirect potential benefits for climate mitigation

This Pillar 1 option can be used by Member States to provide targeted support for ‘sectors or regions where specific types of farming or specific agricultural sectors that are particularly important for economic, social or environmental reasons undergo certain difficulties’. These types of payment can be a useful targeted support for economically vulnerable types of livestock farming, and their main relevance to mitigation is likely to be where they are used to support extensive livestock grazing on permanent pasture, for example in Denmark (Hart *et al.,* 2010).

Member States’ use of voluntary coupled direct payments from 2015

From 2015 most Member States are using some form of direct payments coupled to specific production sectors. 11 Member States have allocated 13 per cent of their Pillar 1 ceiling to voluntary coupled support, nine Member State will use the extra 2 per cent allowance for protein crops and four Member States have been given special allowances (BE, FI, PT and MT) to allocated higher percentages. Nine Member States have allocated less than 8 per cent (CY, DK, EE, EL, IE, LU, NL, AT and UK (Sc) and one Member States is not using voluntary coupled support at all (Germany), with three regions of the UK (E, W, NI) also not using this option. In total, approximately €3.8 billion of funding has been allocated to this measure, as shown in Table 36.

Table 36: Proposed use of voluntary coupled support 2014-20 by sector

Sector	No of MS	% of VCS envelope for 2015	€billion
Beef and veal	24	42	1.7
Milk and dairy products	19	20	0.8
Sheep and goat meat	22	12	0.5
Protein crops	16	10	0.45
Fruit and Vegetables	19	5	0.2
Sugar beet	10	4	0.15

Source: European Commission (2015)[14] with Agra Europe CAP Reform dashboard

The main sectors supported are beef and veal, followed by sheep and goat meat. This support is unlikely to specify or be related to specific climate actions but in supporting and stabilising economically vulnerable systems of livestock production it may support the maintenance of permanent pasture and additionally could enable farmers to adopt climate actions that they might otherwise not be able to afford.

Rural Development Programme implementation with benefits for climate mitigation

The overall aim of rural development policy, funded via the EAFRD, is to promote sustainable rural development in a way that complements the other EU shared management funds as a means of contributing to 'the development of a more territorially and environmentally balanced, climate-friendly and resilient, competitive and innovative Union agricultural sector. It shall also contribute to the development of rural territories'[11]

Member States had a total of 43 rural development measures from which to choose to design their 2007-13 RDPs, organised in three separate axes. For 2014-20 the measures have been rationalised into a set of 19 (plus technical assistance) and the axis structure removed. At least 30 per cent of the EAFRD contribution to each RDP must be reserved for measures relevant to climate change mitigation and adaptation and the environment, but the agri-environment measure (now agri-environment-climate) and the Leader approach remain the only compulsory measures for all Member States.

From the information available it is difficult to assess the extent to which the specific actions mitigation actions identified by this study have or have not been supported under the 2007-13 RDPS (or are likely to be in the 2014-20 programming period). It is clear that there is considerable variation in the extent to which climate mitigation actions are supported in different Member States and regions, and also in the range of EAFRD measures used. However at the level of detail *within* each measure it is much more difficult to identify the specific climate actions to be supported in the 2014-2020 or the extent to which these are tailored to the climate mitigation priorities for the area.

Use of Rural Development Programme measures in 2007-13

Figure 6 draws together information on which measures have been used in the RDPs in different Member States for addressing climate mitigation, as identified in a review of Member State revisions to RDPs at the time of the CAP Health Check[12].

[11] Article 3 of Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005
[12] The source data can be found here: http://enrd.ec.europa.eu/enrd-static/themes/environment/climate-change/en/climate-change_en.html

This indicates that as might be expected, it is the agri-environment, farm modernisation, afforestation and training measures that are used most frequently for this purpose. Indeed all Member States have incorporated some form of climate mitigation actions within their agri-environment measures, all but three use the farm modernisation measure to support efforts to reduce greenhouse gas emissions and all but nine Member States state climate objectives for the use of the afforestation measure. Climate mitigation also features strongly within the use of the training and advice measures.

Figure 6: RDP measures stated as being used for climate mitigation in 20017-13 RDPs

		AT	BE	BG	CY	CZ	DE	DK	EE	EE	EL	ES	FI	FR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
Training	**111**	x			x	x	x	x	x		x	x	x	x	x	x	x			x	x	x	x	x		x	x	x	x
Young farmers	112											x					x						x			x			
Advisory services	114					x	x		x			x			x			x			x			x				x	x
Farm management	115																				x			x					x
Farm modernisation	121	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x
Improving economic value of forests	122														x					x								x	x
Adding value	123	x		x		x		x					x		x		x				x								x
Cooperation for development	124							x					x								x	x							x
Infrastructure	125					x																x					x		x
Natural handicap - mountain	211			x																									
Natural handicap - non-mountain	212			x														x				x							
Natura 2000 / Water framework directive	213																	x											
Agri-environment	214	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Non-productive investments (agriculture)	216														x									x					x
Afforestation of agricultural land	221				x	x	x	x	x	x	x	x	x	x	x		x	x				x	x	x	x			x	x
Agroforestry	222														x														x
Afforestation of non-agricultural land	223			x	x										x					x			x		x				x
Natura 2000	224																	x										x	
Forest-environment	225														x													x	
Restoring forestry potential/Preventative act	226			x											x		x						x						
Non-productive investments (forest)	227														x											x			

Source: Own compilation based on a review by the ENRD of Member States' RDPs post Health Check, carried out in 2009/10.

When the content of the measures is examined further, the way in which Member States have used these measures for climate mitigation purposes become clearer. A selection of examples are set out for a range of measures in the box below.

Examples from 2007-13 RDPs of specific climate mitigation actions, by measure

Farm Modernisation measure (M121):

In Spain, this measure is used to support investments in manure storage and treatment facilities to reduce GHG emissions from livestock production (Baleares, Galicia, Navarra and the Basque Country)

In the UK, the measure is used to support investments for manure storage (E, NI, S, W)

In France, support is offered for investments for manure treatment and processing with a view to reducing ammonia and GHG emissions, for instance coverage of pits and manure treatment equipment. Support is also provided to support investments in precision machinery (see Box 1 below).

In Poland, support is provided for investments in modernisation of manure management facilities and equipment, both for solid manures and liquid slurries

Agri-environment measure (M214):

All regions in Spain used the agri-environment measure to support organic farming and the majority also provided support for integrated production, both of which were identified as being important climate measures (see Table 37). Other measures identified in Spanish RDPs with climate objectives were support for soil conservation techniques, extensive livestock management, maintenance of extensive dryland systems and wetland management.

In the UK, this measure is used to support:

Extensive livestock management and grassland management (E, S, W)

The conversion from conventional to organic production (E, NI, S, W)

Fertiliser management (reducing emissions from plant and soil protection practices (E, NI, W)

Arable reversion to pasture (E, S)

In France, support is provided for:

organic farming (most common measure highlighted for climate);

integrated production (limits on the use of phytosanitary products; extended crop rotations; and diversification of rotations in arable crops);

extensive livestock grazing (extensification of pasture management, involving reduced/no fertiliser use, reduced use of phytosanitary products, actions to maintain/increase soil organic levels); and

soil management (extensive pasture management; avoiding the use of synthetic fertilisers and chemical plant protection products).

In Poland, this measure is used to support:

organic farming;

management of extensive permanent grassland;

under-sowing of winter cover crops to limit leaching and run-off of polluting substances

the creation of buffer zones to limit leaching and run-off of polluting substances

Non-productive investments (M216_):_

- In the UK, this measure is used to fund the restoration and reinstatement of boundary features, woodlands and wetlands (E, S, W)

Afforestation of agricultural land (M221):

- In Spain this measure is used to promote forests for carbon sequestration purposes (afforestation to fight soil erosion and desertification, improvement of forest roads)
- In France support for establishing forests is highlighted as a climate measure
- In Poland support for establishing forests is also highlighted as beneficial for climate

Measures to support training and the provision of advisory services (M111/114):

- In Spain (Castilla La Mancha) these measures are used to increase farmer knowledge and awareness of climatic effects and to enable forest owners to access advisory services on this issue
- In the UK, the training measure is used to increase farmer knowledge and awareness of climatic effects (E, NI, S, W)

- In France, the training measure is used to support training for integrated production, and the reduction in the use of phytosanitary and fertilisation practices as part of integrated farm management
- In Poland, advice is provided for environmentally-friendly production techniques in farming and forestry, which may include a climate dimension although this is not specified

Support for young farmers (M112):

- In Spain (Valencia), a top-up payment is provided to young farmers (€2,000) if they include systems for minimising GHG emissions

Restoring forest's production potential (M226):

- In Poland this measure is considered to benefit climate indirectly, through support for the restoration of forests destroyed by biotic and abiotic factors and for the introduction of mechanisms to prevent forest fires

Table 37: Actions supported under the agri-environment measure for climate purposes in Spain

	Organic farming	Integrated production	Soil conservation techniques	Extensification of livestock	Extensification of pastures management	Conservation agriculture	Extensive agricultural systems of dryland	Management of wetlands
Andalucia	x	x			x	x		
Aragon	x	x	x	x				
Asturias	x		x	x	x			
Baleares	x	x		x				
Canarias	x	x	x	x				
Cantabria	x		x					
Castille y La	x		x				x	
Castille y Le	x	x					x	
Catalunya	x	x	x					x
Extremadur	x	x	x					
Galicia	x	x	x	x				
Madrid	x	x				x		
Murcia	x	x	x				x	x
Navarra	x		x					
Pais Basqu	x	x	x			x		
Rioja	x	x	x	x				
Valencia	x	x	x					x

Source: Own compilation based on a review by the ENRD of Member States' RDPs post Health Check, carried out in 2009/10

Box 1: Examples of the use of RDP measures in Sweden and France

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 10-15 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 fertilisers; 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.

Changes to the structure of Rural Development Programmes for 2014-20

Several changes have been made to the structure of the 2014-2020 RDPs that are relevant to climate mitigation choices for Member States. **At least 30 per cent of the EAFRD contribution to each RDP must be reserved for specific measures relevant to climate change mitigation and adaptation and the environment**. These are the measures for: agri-environment-climate and organic farming, Natura 2000, payments to areas facing natural or other specific constraints, forest-environmental and climate services and forest conservation, environment and climate-related 'non-productive' investments and investments in forest development and viability.

The long-established, compulsory (for Member States) agri-environment measure has, for 2014-20, been widened to an **agri-environment-climate measure** which is intended to *'further encourage farmers and other land managers to serve society as a whole by introducing or continuing to apply agricultural practices contributing to climate change mitigation and adaptation and compatible with the protection and improvement of the environment, the landscape and its features, natural resources, the soil and genetic diversity. In this context the conservation of genetic resources in agriculture and the additional needs of farming systems that are of high nature value should be given specific attention'*. This is one of the most flexible of all CAP support measures and allows Member States the freedom to address climate priorities in a way that reflects the great variety of local bio-physical, climatic, environmental and agronomic conditions across the EU. Agri-environment payments are calculated as the additional costs and income foregone as a result of management requirements going beyond standard practices and regulatory standards. In addition, a key element of the payment calculation is an additional payment for the farmer's transaction costs (the time and effort spent in setting up and administering the contract). This can add a further 20 per cent to the payment calculation (30 per cent for group contracts) and make a crucial difference from the farmers' point of view. However, many managing authorities do not currently add transaction costs to agri-environment payment calculations despite evidence that this can affect uptake (Keenleyside et al, 2012).

For 2014-20, support for **conversion to and maintenance of organic farming systems** is separate from the agri-environment-climate measure, but is similar in structure, with five to seven year annual payments.

The new EAFRD Regulation groups together in one measure a wide range of **investment support,** including improving overall performance of the farm, processing, marketing and development of products, infrastructure improvements and non-productive environmental investments (often required 'up-front' at the start of a five-year agri-environment-climate contract and can be vital to the feasibility of implementing the land management requirements). Rates of investment support can be increased for young farmers, group investments, integrated projects, in some areas of natural constraint (ANC) and investments related to agri-environment-climate and Natura 2000 payments. Other climate-relevant RDP measures available to Member States include, for example, support for improved animal welfare and reduced levels of disease, which could have the impact of improving the GHG intensity of livestock production.

EAFRD is the chief source of EU support for **forest investment and management** (most forest policy and support is determined and delivered independently of the EU, by individual Member States). The suite of eight forestry measures for the 2007-13 RDPs will continue to be broadly the same in 2014-20. These measures have considerable potential for mitigation, carbon sequestration and the protection of existing forest carbon pools. The measures cover investments improving the resilience and mitigation potential of forest ecosystems, environmental afforestation and creation of woodland, the establishment of agroforestry systems and annual management payments for forest-environmental and climate services. Reducing fire risk is an important mitigation and adaptation action for forests, especially in Southern Europe, and the measure for forest fire prevention provides support for land management operations that maintain protective infrastructure, such as firebreaks. Additionally the measure supporting the restoration of agricultural potential after natural disasters or catastrophic events could potentially be used to fund habitat restoration actions after fire, such as the reinstatement of grazing on scrubland prone to wildfire.

The **Leader approach** has a strong potential to use local action groups to deliver innovative projects for training and implementation of mitigation projects at a landscape scale or group scale, and has been used in the United Kingdom to support local projects renewable energy biomass, for example.

The provision of advice, support and training for farmers is crucial for the successful implementation of climate mitigation actions. There is still a substantial unmet need for advice and support amongst farmers in the EU - in 2008 only around 5 per cent of farmers receiving direct payments were given one-to-one advice (European Commission, 2010a). Member States are obliged to set up a **Farm Advisory System** which from 2015 must cover the following: cross-compliance (SMR and GAEC); greening requirements; farm level requirements under EU water and pesticide legislation; and RDP measures for farm modernisation, competitiveness building, sectoral integration, innovation, market orientation and promoting entrepreneurship. Member States can choose to offer a much wider range of advice through the Farm Advisory System, including advice on a list of specific topics relevant to climate change mitigation and adaptation, biodiversity and water. In addition to the provision of advice, Member States can use another Pillar 2 measure to support knowledge transfer and information, including the provision of vocational training and skills training, workshops and coaching, demonstration activities and farm visits and short-term farm management exchanges. Funding can also be provided to train the staff providing the service and to cover the costs to the farmers of attending these events. Training and information exchange can be tailored to support any combination of measures at any degree of detail.

The new **European Innovation Partnership (EIP) for Agricultural Productivity and Sustainability** will be supported through rural development policy through the development of an EIP network at the EU level and 'Operational Groups' at the national level, which will be set up by 'interested actors' in the agricultural and food sector to develop innovative projects to enhance productivity and sustainable resource management. This is a novel initiative and offers significant opportunities to integrate climate adaptation into the priorities of the new Operational Groups and the projects that they subsequently carry out. The rural development **co-operation measure**, whose scope has been considerably broadened compared to the previous programming period, represents a very important instrument to implement the EIP.

Planned use of Rural Development Programme measures in 2014-20

By mid-2015 almost half of the 118 RDPs for the 2014-2020 programming period had been approved, and for 22 of these summary information is available about how climate mitigation and adaptation is addressed. It must be stressed that this sample is *not* a representative of all the RDPs (e.g. in terms of rural development priorities, farming and forestry systems, soils or socio-economic problems) – it is simply the sample that was available at the time of writing.

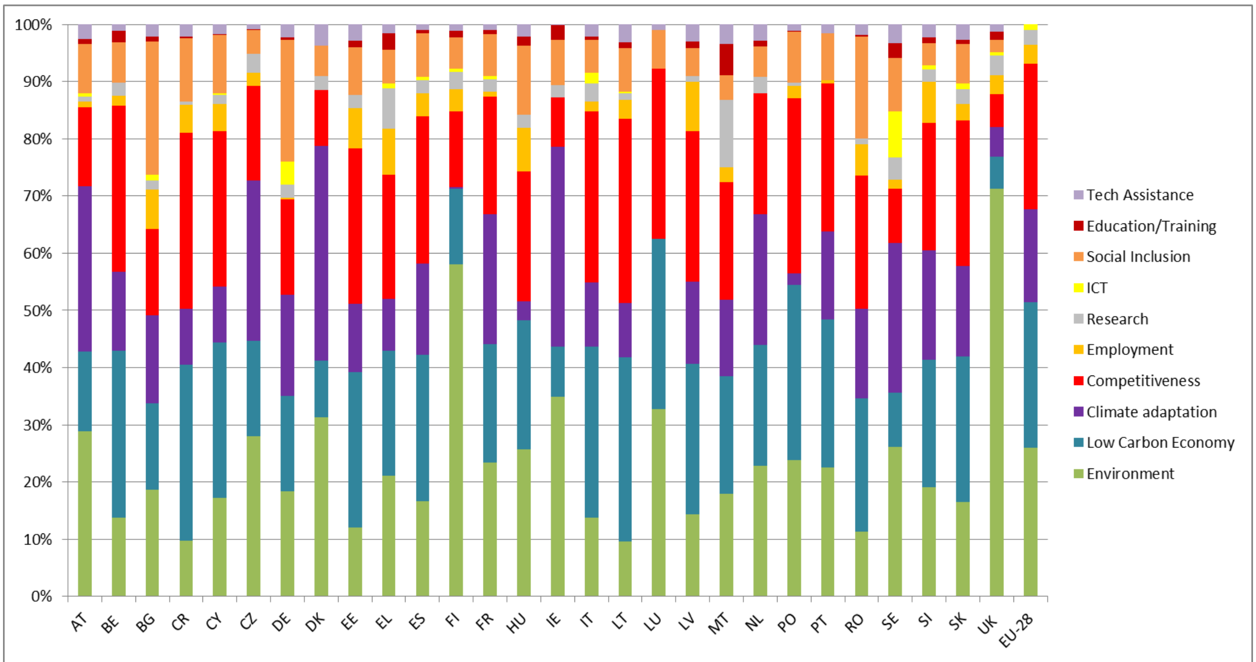
The following analysis examines available data for some of the 2014-20 RDPs[13] on: the EAFRD allocations to Partnership Agreement priorities; the climate challenges addressed by the programme; the proportion of total climate expenditure allocated to different measures; and gives examples of specific climate actions and target indicators.

EAFRD allocations to Partnership Agreement priorities

Member States had to decide at the start of the 2014-20 programming period how they wished allocate their total EAFRD funding (and other ESI funds) among ten thematic objectives set out in the Common Provisions Regulation, including those for a low carbon economy and the environment. These are set out in a national "Partnership Agreement" which is approved by the European Commission. The choice of thematic objectives included in the Partnership Agreement has to be consistently transposed at the level of the six Union priorities for Rural Development to be selected and included in each national or regional rural development programme. Figure 7 gives an indication of the wide differences between Member States in the apportionment of their EAFRD funding along the ten relevant thematic objectives included in the Partnership Agreements.

It is not possible to establish from these figures what proportion of funding is allocated to supporting climate mitigation actions on agricultural and forest land, as these actions could be covered under the ‘environmental’, ‘low carbon economy’ or even possibly under the ‘competitiveness’ category, depending on the anticipated focus of the expenditure. Also, in the case of forestry ‘climate adaptation’ is likely to include actions that also make a significant contribution to climate mitigation.

Figure 7: EAFRD allocations to Partnership Agreement Priorities



Source: Own compilation using data from Partnership Agreements.

[13] By mid-2015 almost half of the 118 RDPs for the 2014-2020 programming period had been approved, and for 22 of these summary information is available about how climate mitigation is addressed.

Climate challenges identified in 2014-20 RDPs

In preparing the RDP Member States/regions are expected to identify the specific challenges that the RDP will address. The challenges related to climate (both adaptation and mitigation) are described in the summaries of 22 RDPs, albeit in slightly different ways. Figure 8 shows those RDPs where the identified climate challenges appear to be relevant to one or more climate mitigation actions identified in this study. However it is not always possible to be certain that these all relate to agriculture and forestry land management, for example in broad challenges such as ‘energy efficiency’ or ‘reduce GHG emissions’ which might refer to other sectors in the rural economy, although in other cases the challenges are very specific to one or both sectors. Also, in the two Member States which have multiple RDPs in this sample (Germany and Portugal) the challenges may reflect both regional and national priorities.

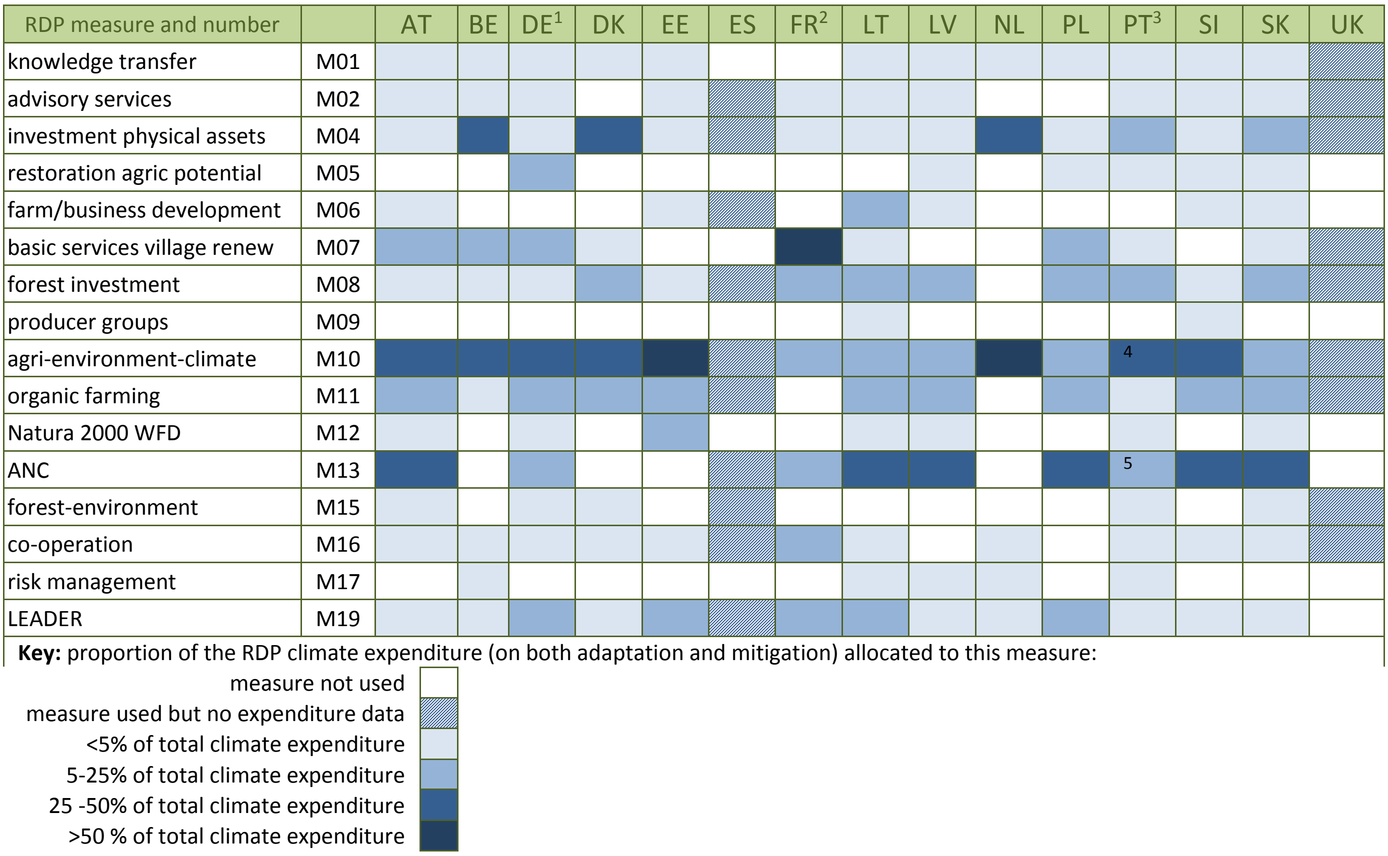
Figure 8 Identified climate challenges relevant to the mitigation actions identified in this study (for 22 RDPs 2014-20)

RDP for Member State or region	Climate challenges to be met (only challenges relevant to the mitigation actions identified in this study)
AT, DE-B, DE-H, DE-NRW, DE-S, EE, LV, NL,	reduce GHG emissions
DK, EE, ES, SI	reduce methane emissions
BE, DE-MP, ES, LV, SI	C sequestration/storage in forests
AT, BE, EE	C sequestration/storage in agriculture
BE, DE-H, DE-MP, DE-NRW, EE, ES, FR, PT UK-E,	soil protection/management/reduce erosion
AT, ES, DE-B, PL	preservation soil organic matter
DE-B, DE-NRW	preservation/restoration of wetlands/peatland
DE-NRW, ES	preservation of grassland/carbon sinks
DE-NRW, DE-S, DE-SA, FR, PT, PT-A, PT-M	forests: protection/restructuring/regeneration/economic use
BE	afforestation
PT, PT-A, PT-M	innovation/R&D/support for agroforestry
EE, UK-E	reduce risk of forest fires
BE, DE-B, DE-MP, EE, FR, UK-E	protection/restoration management of habitats/landscape features
DE-S, DE-SA, ES, LT, PL	optimise/reduce fertiliser use
PT	enhance soil fertility
DK, ES	reduce nitrous oxide emissions
LT	reduce risk of endemic animal disease
SI	increase efficiency cattle breeding
BE, DE-B, DE-MP, DE-SA, EE, ES, NL,PT, SI	energy efficiency
DE-S	resource efficiency
	Source: own compilation, using 19 RDP summaries from 14 Member States: AT, BE, DE-B, DE-H, DE-MP, DE-NRW, DE-S, DE-SA, DK, EE, ES, FR, LT, LV, NL, PL, PT, PT-A, PT-M, SI, SK and UK-E (European Commission 2015, unpublished)

Allocation of climate expenditure to RDP measures 2014-20

For the 22 RDPs (15 Member States) for which summaries are available it is possible to identify which measures are to be used for climate priorities (both mitigation and adaptation) and the proportion of the total climate expenditure for the RDP that is allocated to each measure. A wide range of measures are used and the proportion of the total climate funding allocated seems partly to reflect the different relative costs between land-based annual payments and investment measures (e.g. agri-environment-climate, organic farming) and capacity building measures (e.g. knowledge transfer, information and advisory services, co-operation). There is also considerable variation between Member States in the proportion of their climate expenditure allocated to a specific measure, as shown in Figure 9. Similar variation is seen within the two Member States which have several RDPs in this sample (six for Germany and three for Portugal); for example the German Länder allocate quite different proportions of their climate expenditure to the measures for agri-environment-climate (from 7.3 to 45.9 per cent), organic farming (9.5 to 49 per cent) and LEADER (2.3 to 39.8 per cent).

Figure 9 RDP 2014-20 expenditure on climate adaptation and mitigation by measure



Notes:

1 refers to RDPs for six German Lander; percentage refers to the average for the RDPs (of the 6 analysed) that used this measure

2 refers only to RDP for Mayotte

3 refers to RDPs for mainland PT, Madeira and Azores.

4 percentage refers to is 25-50%)

5 percentage refers to mainland PT (Madeira and Azores are 25-50%)

Source: own compilation, using 19 RDP summaries from 14 Member States: AT, BE, DE-B, DE-H, DE-MP, DE-NRW, DE-S, DE-SA, DK, EE, ES, FR-M, LT, LV, NL, PL, PT, PT-A, PT-M, SI, SK and UK-E (European Commission 2015, unpublished)

Except where the measure corresponds to a specific mitigation action (e.g. afforestation, agroforestry establishment) the summary information at measure level is insufficiently detailed to correlate with specific climate actions identified in this study. Most measures cover a wide range of schemes and activities, and the summary covers both climate mitigation and adaptation objectives, often within the same measure. Some examples of the type of climate mitigation actions that Member State plan to support under different measures in 2014-20 are shown in the box below.

Examples from 2014-20 RDPs of specific climate mitigation actions, by measure

M01 Knowledge transfer and information actions: training, coaching and demonstration activities to stimulate innovation in: low emission agriculture, energy efficiency and uptake of renewables (NL) … knowledge and skills in: efficiency of energy utilisation in agriculture; reduction of nitrous oxide and methane emissions from soil; and carbon dioxide sequestration in agriculture and forestry (SK)...

M04 Investments in physical assets: …construction and repair of livestock housing and breeding of livestock using new technologies for the reduction of GHG emissions (SK)… non productive investments linked to agri-environment-climate objectives (e.g. planting hedges of resilient forest species) (FR-Mayotte) ... investments in improved resource efficiency or animal health and welfare (UK-England).

M06 Farm and business development: young farmers will be supported whose business plan shows a contribution to climate mitigation e.g. introduction of technologies which reduce environmental pollution and improve animal welfare (SI).

M07 Basic services and village renewal: preservation of forests and other natural areas (physical investments and studies) with priority given to degraded land dealing with anthropogenic pressures (FR-Mayotte)

M10 Agri-environment-climate payments for: … sustainable practices, protection of soil and water, orchards, traditional fruit plantations, valuable habitats inside and outside Natura 2000 (PL) … preservation of natural resources including bio diverse orchards, shrub windbreaks, pastures and grasslands (PT-Azores) … special attention to protection of groundwater through precise and accurate fertilization; protection against soil erosion on selected ploughed land; protection of semi-natural and natural grassland habitats (SK) ... fighting erosion, maintaining soil fertility and supporting tree-planting in wooded areas (e.g. bushes and woody vegetation on rivers' edge, agroforestry systems, sloping land (FR-Mayotte) … environmental cultivation, green cover, permanent crops, mowing mountain meadows, cultivation of soils prone to leaching (AT).

M12 Natura 2000 annual compensation payments: for permanent grassland and forest land (SK) … for foresters (PT-Madeira).

M13 Payments to areas facing natural or other specific constraints: in agroforestry areas, maintenance of multiple cropping cultivation methods with low impact on the environment and agricultural systems that enhance woodlands with high carbon storage capacity ((FR-Mayotte).

M16 Co-operation: joint activities to mitigate and adapt to climate change, preparation of management plans for forest maintenance, or equivalent tools SK) … develop initiatives to tackle animal health and welfare issues (UK-England).

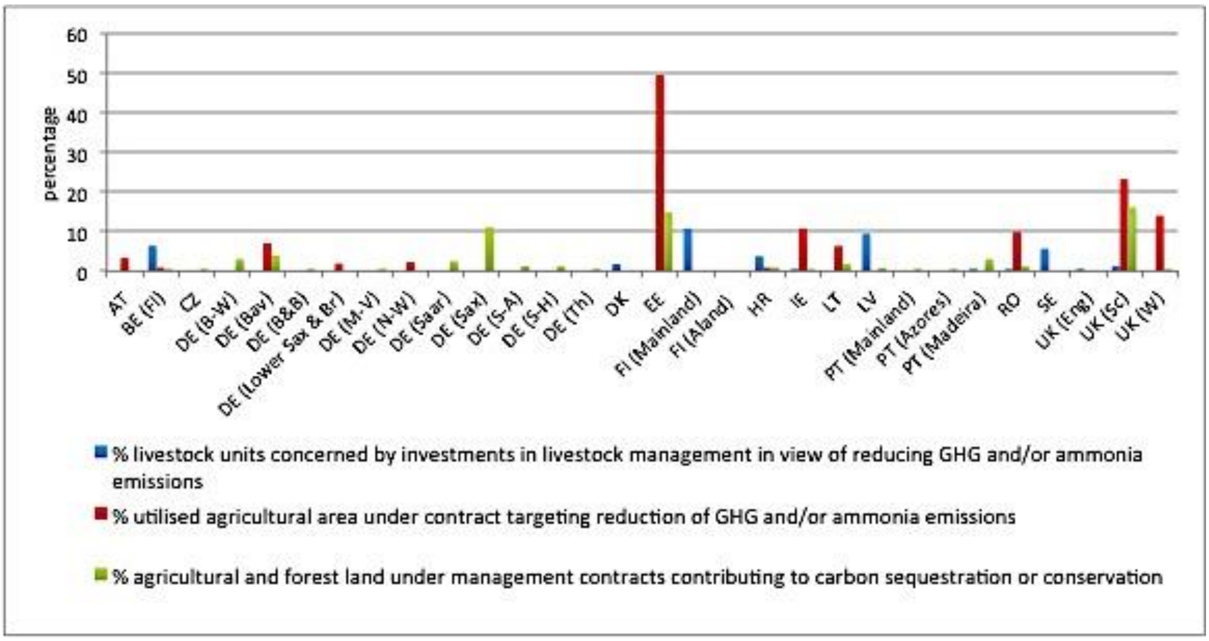
M19 Support for LEADER local development: projects that implement community led local development strategies and have innovation, environment and climate change as a focus (NL).

Note: examples have not been included for the three RDP measures that are likely to maintain or enhance C sequestration irrespective of the specific activities supported.

These are: M08 investments in forest area development and improvement of the viability of forests; M15 forest environmental and climate services and forest conservation; and M11 organic farming.

Some additional information on the scale of proposed support can be gleaned from the target indicators for EAFRD priorities 5d (reducing GHG and NH3) and 5e (5e Carbon conservation and sequestration) where these have been identified by Member States (see Figure 10).

Figure 10 Examples of target uptake indictors for EAFRD priorities 5d and 5e (2014-20 RDPs)



Source: own compilation using (ref tbc)

Annex 6: March 2015 Workshop Report

Introduction

The primary objective of the meta-review of Common Agricultural Policy (CAP) mainstreaming study is to identify and assess the most effective climate measures that could feasibly be introduced, improved or scaled-up using policy tools within both Pillars of the CAP. A second key objective is to assist in the analysis of mitigation potential from AFOLU, in accordance with international reporting accounting rules and/or frameworks under the UNFCCC and the Kyoto Protocol.

As port or this project Ricardo-AEA and IEEP are required to deliver stakeholder engagement workshops. The first of these workshops was held on the 6th March.

A key objective of this workshop was to gather information from delegates about the opportunities and challenges in implementing GHG mitigation actions at a national and regional level. Also an opportunity to:

- Share new information.
- Challenge current thinking.
- Exchange ideas.
- Increase awareness and understanding.
- Provide opportunities for networking.

This report summarises the first workshop.

Organisation of the Workshop

Ricardo-AEA was responsible for all practical aspects of preparing and organising the workshops, including logistics related to the venue, invitations of participants, developing a system for online registrations, providing confirmations and travel information.

Venue

In early February 2015 the European Commission confirmed the date of the workshop and the content was agreed with the project team. The venue was the Jenkins room at the Charlemagne Building. This was a large room holding 150 in a circular boardroom seating style.

Ricardo-AEA confirmed all the arrangements regarding the access times, catering (1 servings of tea/coffee and buffet lunch with refreshments), audio-visual, flipcharts, final numbers, names and logistics with the appropriate European Commission contact.

Invitations

The first invitation email was sent to 58 individuals on Tuesday 17th February 2015. The first mailing resulted in few registrations but this increased the following Tuesday when a reminder was sent. Please note that the second mailing included 16 additional contacts. This pattern is perfectly normal as delegates often need to see the invitation more than once before they take action or need time to seek approval from their budget holder for time and travel. Regular reports were supplied to the EC on the number of registrations to date.

Below is a table showing the steady increase:

Date	Number
17/03/15	2
18/03/15	4
19/03/15	8
20/03/15	2
23/03/15	3
24/03/15	8
25/03/15	5
26/03/15	8
27/03/15	2
02/03/15	12
03/03/15	12
Total	**66**

We also had a total of 10 individuals who did not register using the online registration but sent an email directly to the event manager or actually just turned up on the day.

Ricardo-AEA provided a secure online web–based system for bookings and management of the workshop. The website address was http://capmetaworkshop.aeasolutions.co.uk/ with the user name 'CAPClima' and the password 'Workshop'. Each delegate was asked to provide up to 50 words about their main fields of interest/expertise during the registration process along with any dietary requirements. Upon on registration delegates received an automatic confirmation email with more details about the workshop and travel information (see Appendix 1 for examples including the invite).

On Tuesday 3rd March 2015 registered delegates received an email reminding them about the workshop, a list of the registered delegates to date with their interest/expertise, the final agenda and the briefing note (see Appendix 3). The final briefing note provided information on the objectives of the day and to prepare delegates to share relevant information which will feed in to the next phase of this project.

Accommodation for delegates was not arranged but a list of hotels was provided.

Format of the Workshop

The format of the workshop included presentations and breakout sessions. The agenda was as follows:

Time	Registration and coffee – morning session chaired by Simon Kay, European Commission	
10.15	Introduction and background	Peter Wehrheim, European Commission
10.30	Technical assessment and screening of actions to reduce GHG	J Webb, Ricardo-AEA
11.15	Climate action in the CAP	Clunie Keenleyside, IEEP
	There will be opportunities to ask **questions** after each speaker session	
12.00	**Lunch – Afternoon session chaired by David Baldock, IEEP**	
1.00	Introduction to ranking criteria & breakout sessions	Hugh Martineau, Ricardo-AEA
1.10	Review and assess the feasibility of climate actions based on the ranking criteria – In groups.	Breakout sessions, **Facilitators** Hugh Martineau David Baldock Clunie Keenleyside J Webb
2.30	Feedback from breakout sessions	Facilitators
3.15	Summary and close	Simon Kay, European Commission and David Baldock, IEEP
3.30	**Close**	

After an introduction and overview from the European Commission, the first presentation was given by J Webb and covered task 1.1 the approach and outcomes of the screening of mitigation actions.

A presentation was then given by Clunie Keenleyside and outlined how climate actions currently fit within CAP measures.

Break-out Session

The breakout session was discussed thoroughly with the European Commission in the weeks leading up to the workshop. It was agreed that the overall objective of the break-out session was too:

- Gather information to assist and inform the ranking of climate actions
    - How relevant are actions to sectors and geographic areas
- To discuss the practicalities of scaling up or implementation new of actions from those identified
    - To what degree actions are already implemented through CAP
    - How can they be improved
    - What actions should be considered in the future and what are the implications for affected groups

The breakout sessions was interactive and intended to generate useful discussion relating to the implementation of actions. The delegates were split into four groups prior to the workshop:

- Land Use
- Crop Production
- Livestock Production
- Fertiliser, Manure and Soil Management

Notes from the breakout sessions can be found in appendix 5.

Figure 2 Photos from the Breakout Session in Brussels

Badges and Delegate Packs

Ricardo-AEA provided delegate badges, printed the agenda, participant list and event feedback questionnaire.

On the Day Event Management

The workshop was attended by 3 members of the Ricardo-AEA team: two technical team members and an event manage. From IEEP two technical team members attended.

Ricardo-AEA ensured the rooms were set up with the correct equipment; prepared the registration area, registered delegates, distributed the delegate packs and badges. Ricardo-AEA also liaised with speakers and the European Commission regarding any last minute changes to requirements.

On the day the workshop was attended by 69 delegates (7 no shows). The delegates were from the following countries:

(The full list of attendees is in Appendix 3).

Delegates Country of Origin	Number
Austria	2
Belgium	22
Denmark	3
Estonia	1
Finland	1
France	2
Germany	4
Ireland	2
Italy	5
Latvia	1
Luxembourg	2
Malta	2
Poland	3
Spain	2
Sweden	1
The Netherlands	2
UK	10
Not supplied	4

It is no surprise that the host country had the largest number of attendees i.e. Belgium 22.

The speaker's final presentations were converted to PDF and uploaded to the online registration website in a single ZIP file. See Figure 3.

At the end of the event, Ricardo-AEA logged any amended details provided by delegates.

After the workshops

Thank you emails were sent to the participants. Along with informing participants of the availability to download the presentations from the registration website. There was also a reminder to complete the feedback form. Delegates were provided with a PDF of the European Commission's publication entitled 'Mainstreaming Climate Change into Rural Development Policy' for their information.

Delegates Feedback

Introduction

Ricardo-AEA developed a feedback questionnaire to assess whether attendees found value in the workshop and whether they would participate in a CAP event again (see Appendix 4). The questionnaire gathered information on:

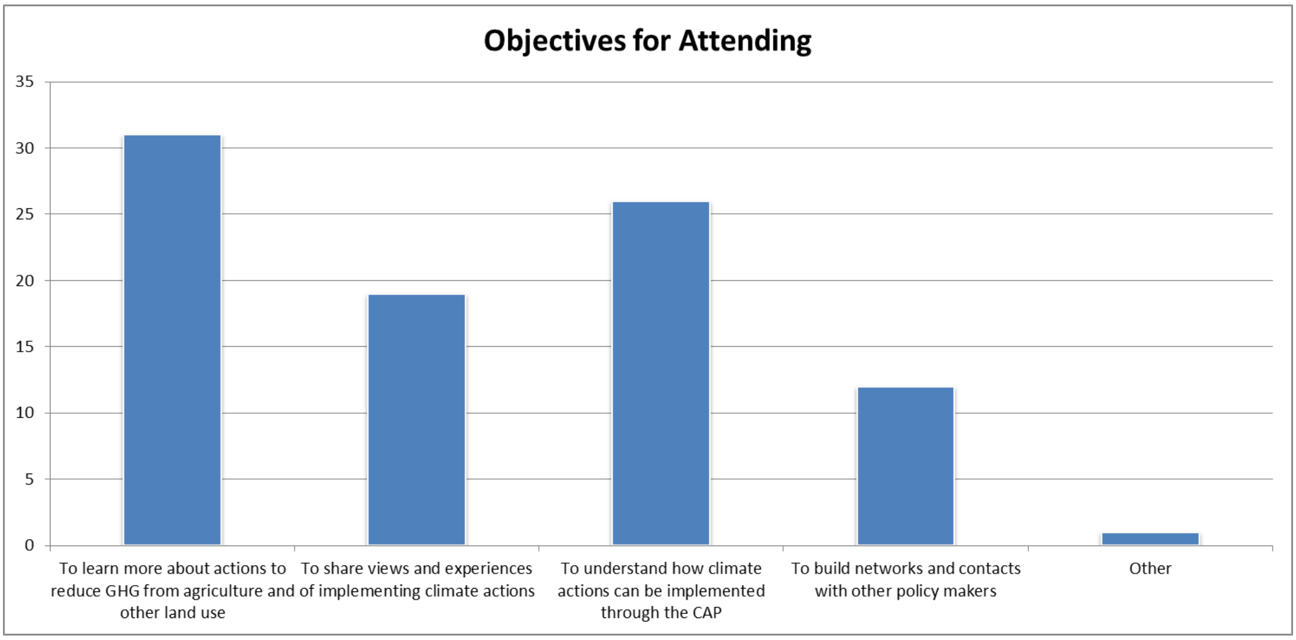
- Participant characteristics;
- Objectives for attending;
- Reactions to the presentations and breakout sessions;
- Aspects that were particularly valuable and areas for improvement;
- Event organisation;
- Possible attendance at future information exchange;
- Any additional comments.

Delegates were reminded during the day of the importance of completing the questionnaire and were also sent a copy with the thank you email, for those that did not complete it on the day. This section of the report will provide the statistical analysis of the responses in the form of percentages, graphics and feedback on the open-ended questions. All the data has been sent to the EC for their own files.

Feedback

35 delegates completed a feedback form which representative 51% of the total delegates. Of the 35 people that completed a questionnaire, 21 were policy officers, 3 were technical experts, 8 were researchers and 3 delegates classed themselves as ‘other’ which included one senior officer, one trainee and one Head of Office.

Delegates were asked their objectives for attending the workshop. A slightly higher number of delegates wished to learn about actions to reduce GHG from agriculture and other land use followed by to understand how climate actions can be implemented through the CAP.



(Please note that nearly all the delegates selected more than one answer)

Only one delegate indicated their ‘other’ reason for attending: To link with research programmes.

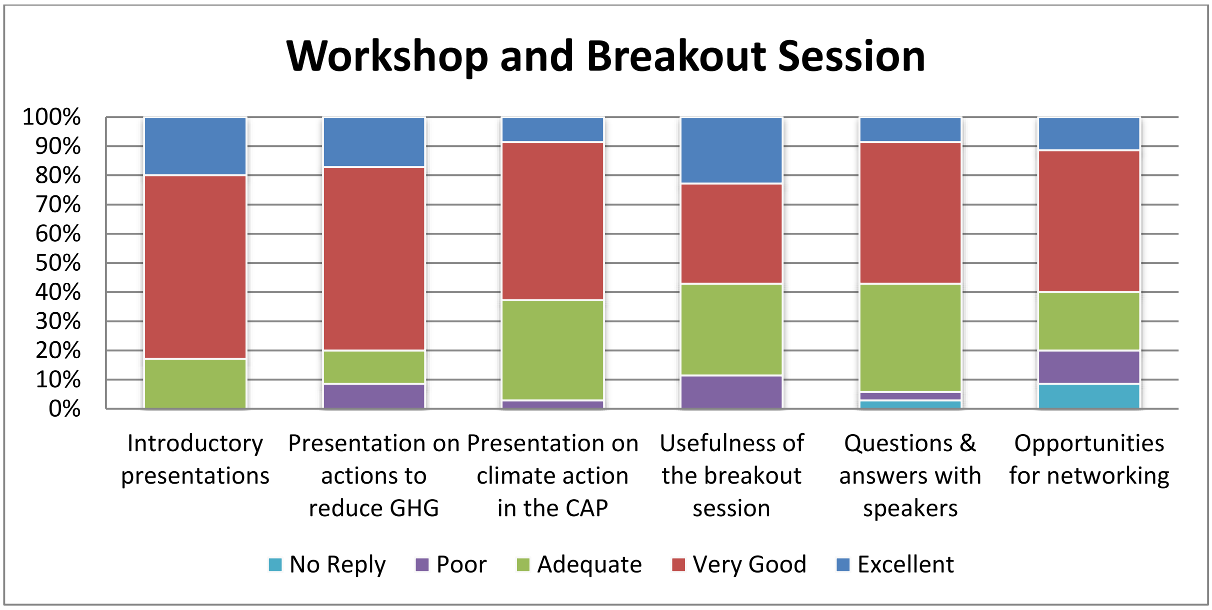
Delegates were asked whether their objectives for attending the workshop had been met and the results were:

Did the event meet your objectives	Percentage
Yes, fully	69%
Yes, partially	6%
No	25%

Of those delegates who stated 'no' gave the following reasons:

- No reason supplied – 7
- "It was nothing new" – 1
- "Not yet" – 1

The highest proportion of 'excellent' ratings was for both the introductory presentations and the presentation on actions to reduce GHG. The highest proportion of 'adequate' ratings was the opportunities for questions & answers with speakers (37%).



A range of answers were given for what aspects of the workshop had been most valuable. The comments were:

- Finding out others MS experiences.
- The discussion and hearing about more measures in other counties.
- Content of the presentations and discussion.
- The presentation with the slide of projects within the EU and the breakout session sharing of data.
- Overview of study being performed and ways in which local/regional measures can be improved to achieve better GHG reductions.
- Recognising that the audience are all working together on these challenges.
- Learning about how the study is developing.
- Breakout sessions.

- The explanations of CAP and the measures available information and well thought through.
- Discussion of the CAP effects.
- Networking.
- Breakout session - share views and experiences. Networking.
- The dissemination of actions to reduce GHG from agriculture.
- Breakout and discussion - good exchange of experiences.
- Review in groups.
- There could have been more time for networking and getting to know each other, maybe a simple fare-well drink at the end of the workshop would have helped
- The breakout session was particularly interesting because it developed a debate on the effectiveness and feasibility of each mitigation action.
- The discussion in groups.

A broad range of responses were given to how future workshops could be improved. The below has been organised into main themes:

Venue Facilities:

- Separate rooms for groups for better hearing.
- Separate rooms for breakout groups - difficult to hear at times.
- More practical room.
- Breakout session should be in separate rooms to allow more focus on discussion.
- The group discussion was very difficult to follow because of the noise in the room (the other discussions).
- Difficult room for the working groups.
- Separate rooms for the break-out sessions, they were good, but could have been better when there was less noise.
- The breakout sessions to noisy to get to know each other well.
- The breakout sessions in a different room.
- Wider groups, break out format not great in the room. Too noisy.
- More space and time for breakout sessions.
- Need separate breakout rooms.

Breakout Groups:

- More time for the breakout sessions.
- Fluctuating the sessions / not everyone had the chance to give their input during the breakout sessions.
- More delegation in the breakout sessions.
- The breakout: some help in the process to keep the group focussed on the questions for the leader.
- Better opportunities for the breakout session.
- Interactions should be better facilitated.
- A kind of world café setting so that it would be possible to attend all the breakout sessions.

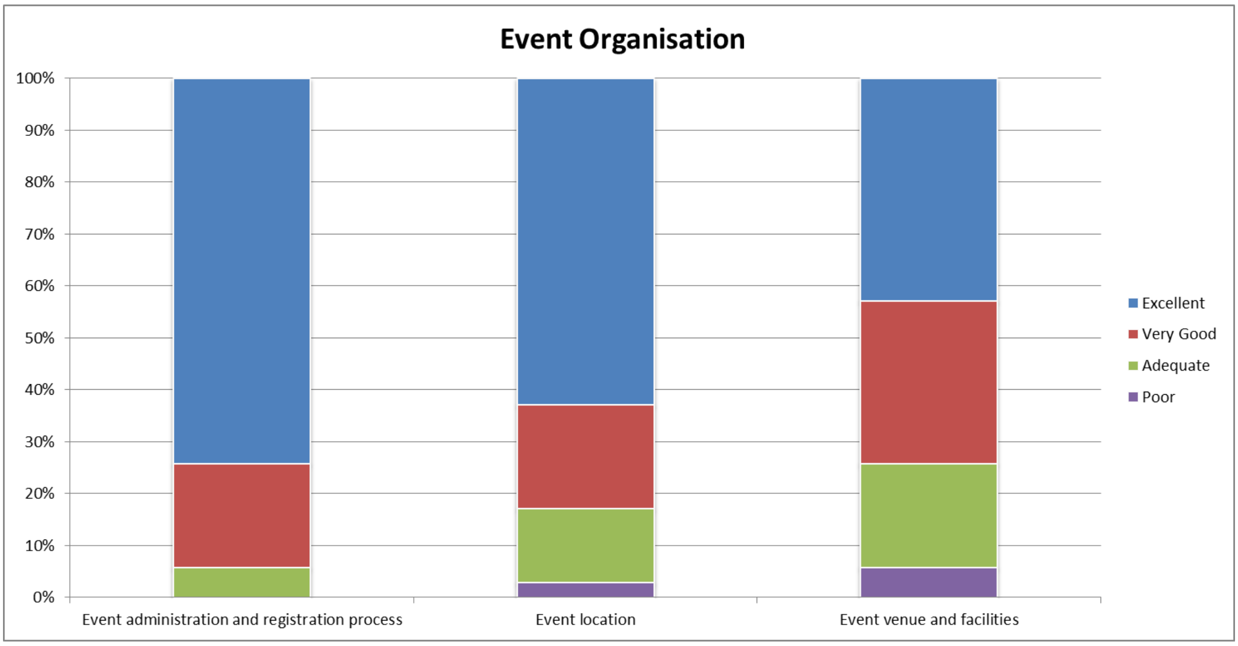
Other Suggestions:

- Provide hand-outs and slides.
- Quantify and present making a GHG reduction measures!
- Would like café style across topics would be useful.
- More time and more thorough presentations of mitigations options.
- More time!
- Leave more time.
- More opportunities to build networks.
- Make it longer.
- More opportunity for networking, There was a huge and very interesting audience. Everyone can be of high value to each other when we can really get to know each other. Only lunch for one hour leaves time to get to know approximately 5 new persons.
- Allow more ambitious discussion to take place outside of the CAP current structure.

General Comments:

- I found the Q&A session and the groups very interesting and stimulating.
- More food at lunch.
- Not sure you can - all very good. Well done!

Feedback on the logistics was very positive, with most respondents thinking that they were excellent or very good.



There were several additional comments:

- Thank you for the workshop.
- It was an interesting day.
- It was a very nice working conference, I think with good results.
- Poor venue and facilities due to no breakout rooms.
- Offer some drinks at close out - for more opportunities for networking.

- Presentations should have been distributed before the meeting. More information on mitigation options should be published. Early warning of future meetings. More analysis of innovative and integrated approaches (grain - grass conversion - Grass Processed in bio refineries, Extraction of high value amino acids glycine and methionine. Improving animal diets/improving productivity.
- The room was unhelpful.
- Working groups a little difficult hence 'adequate'.
- No break out rooms hence 'poor'.
- Separate rooms' maybe a better solution.
- Meeting was short notice.
- Workshop was very short. The groups should consult in different rooms. Topics discussed should have not been fixed.
- With better facilities it could have been even better.
- E.g. separate rooms for breakout sessions, more people would have shared their knowledge.
- There was a good spirit in the room, so despite the noise from other groups, everyone was willing to help to get good results.
- A simple fare-well drink (non-alcoholic!) at the end might have created another network opportunity (or extra mid-afternoon break with coffee/tea).
- An idea for the next time: a climate friendly lunch, with enough tasty and innovative meat & dairy replacers. And fresh food from the neighbourhood of Brussels.

Conclusions

The workshop provided a good opportunity for a positive exchange of views, ideas, best practice in implementing GHG mitigation actions at a national and regional level.

Delegates were asked whether they wished to receive an invitation to the next workshop and the overwhelming response was yes by all those delegates who completed the feedback form. Discussions have begun on the format and timings for the next two workshops.

Areas to address

Breakout Session: Ideally, we would have had a longer period of time for the breakout sessions with each having a presentation on the detail relating to each of the actions being reviewed. Although delegates were provided with specific questions relating to the actions being reviewed in advance of the meeting, we cannot rely on this being read and understood.

Presentation/Presentations: Ostensibly too UK focussed. For the next workshops we should try and incorporate more material from the Commission and other member states potentially.

Venue: Ensure the venue is better equipped for breakout sessions and more food is available. Despite being ordering catering for 75 (8 more people than attended) the venue provided less savoury food was provided.

Generally, the attendance was excellent given the very short timescales for publicising and registration. The responses from delegates was positive and where criticism was made it was relating to the venue layout which we were unable do very much about.

The project team managed to gather a great deal of useful information which will valuable in delivering the project outputs. (Appendix 5 – notes from breakout groups)

Appendix 1 – Invite and Confirmation Email

European Commission

CLIMATE ACTION

Dear

Workshop Invitation

Promoting climate mitigation on agricultural and forest land through the CAP

Friday 6 March 2015

The role that agricultural land and forest areas play in reducing GHG emissions and enhancing their potential as carbon sinks is critical as a means of addressing the significant climate challenges we face. Finding the most effective means of doing this and making the most of the available policy instruments is of paramount importance.

The Commission is working with Member States to assess how to enhance, improve, or implement new climate mitigation actions. As part of a study for DG CLIMA, Ricardo-AEA and the Institute for European Environmental Policy are currently reviewing information from Commission studies and scientific literature to assess the most effective climate measures that could feasibly be introduced, improved or scaled-up on agricultural land and forest areas.

As part of this study a workshop will be held to:

1. Share the initial findings of a study for DG CLIMA which identifies key mitigation actions for agricultural and forestry land, reviews if and how these have been funded via the CAP to date and assesses the extent to which they could be implemented in the future, taking account of differing situations in the EU and within the context of a new climate policy framework post 2020 (for an outline of the project, see box below).
2. Provide detail on the review of the key mitigation actions identified as a priority for reducing GHG emissions on agricultural and forest land.
3. Give participants an opportunity for detailed discussion on the shortlist of actions to provide views and information on the practicality of applying the actions in particular regions or farming systems, particularly to identify:
    a. Are there certain measures that have been particularly effective in reducing GHG emissions in the 2007-13 programming period? If so, what are the factors that have influenced this?
    b. Why certain measures do not feature currently under the CAP, particularly Rural Development Programmes – what are the limiting factors – cost, issues of implementation on the ground, advice provision, impact on farming or forestry operations etc?
    c. Which measures might potentially be more attractive in future given changing technologies etc.
4. To share experiences between Member States

The workshop is free to attend and will take place in Charlemagne Building, Rue de la Loi 170, B-1000 Brussels on Friday 06 March 2015 from 10:00 to 15:30. As an important stakeholder in this policy area we would like to invite you, or an alternative representative from your organisation, to attend the workshop.

The presentations will be in English with no translation facilities.

Please register online (http://capmetaworkshop.aeasolutions.co.uk/) by Tuesday 03 March 2015 using the user name 'CAPClima' and the password 'Workshop'.

Further details are attached.

If you have any questions or need any additional information, please feel free to contact me by telephone +44 1235 753291 or email Jemma.Howland@ricardo-aea.com.

We look forward to welcoming you in Brussels.

Kind regards,

Jemma Howland
Senior Consultant
Ricardo-AEA

I work the following hours:

Monday - Thursday 7.45am to 3.15pm

Friday 8.30am to 12.00pm

Annex 7: September 2015 Workshop Report

Introduction

The primary objective of the meta-review of Common Agricultural Policy (CAP) mainstreaming study is to identify and assess the most effective climate measures that could feasibly be introduced, improved or scaled-up using policy tools within both Pillars of the CAP. A second key objective is to assist in the analysis of mitigation potential from AFOLU, in accordance with international reporting accounting rules and/or frameworks under the UNFCCC and the Kyoto Protocol.

The outputs and final outcomes of this project were to include:

- Reports: Each task to result in a report, to be delivered at the end of appropriate quarterly period.
- Workshops: Ricardo-AEA to organise three stakeholder workshops, in months 3, 6 and 9, including arrangement and financing of the premises and invitation of key experts and facilitators.
    - The workshops to be held in accordance with the agreed geographical locations outlined in the tender proposal.
    - Each workshop deliverable to be concluded with a summary of the workshop results.

The first workshop was held on the 6th March 2015, in Brussels at the Charlemagne Building. It was decided that rather than holding two further events a two-day programme would be provided. A key objective of the events was to gather information from delegates about the opportunities and challenges in implementing GHG mitigation actions at a national and regional level.

Organisation of the Workshop

Introduction

Ricardo-AEA was responsible for all practical aspects of preparing and organising the workshops, including logistics related to the venue, invitations of participants, developing a system for online registrations, providing confirmations and travel information. The Commission organised the speakers and panel members for day 1 and Ricardo-AEA was responsible for planning the speakers on day 2. Ricardo-AEA and the Commission worked closely together on planning the breakout sessions.

Venue

In our proposal our price assumption was based on the organisation and delivery of three one day workshops with a maximum of 40 attendees per work shop (including venue, catering, equipment hire, and printed materials). To date we have organised one workshop which was held on the 6th March 2015. We registered 76 delegates and 69 attended on the day. The Commission wished to hold the next two workshops as a 2-day event in September with an evening drinks reception in Brussels. We were asked to identify a venue that can accommodate 150 delegates fulfilling the below brief:

Day 1

Full day of content.

Social – drinks reception in the evening.

Day 2

End at 12pm for the formal agenda but the afternoon may have informal networking and therefore venue charges are still incurred for the afternoon.

Requirements for the two day event:

- 1 main room for 150 (to double up as a break out room) in theatre style
- 3 syndicate meeting rooms on day one only
- Finger buffet lunch + dessert each day
- Coffee/tea and biscuits per person (3 servings each) per day
- Drinks reception in a private room – one drink per person, either soft, wine or beer.

Plus assortment of hot and cold canapés, 4 per person

- Screen and LCD projector in each room
- Flipchart in each room
- Free and good quality WiFi
- Laptop clicker - one per room
- Microphone for the main meeting room

After our extensive search we identified the Royal Windsor as being available on Monday 14th and Tuesday 15th September 2015 and meeting the requirements. The Commission arrange for a contract variation to cover the additional expense.

Ricardo-AEA confirmed all the arrangements regarding the access times, catering, audio-visual, flipcharts, final numbers, names and logistics with the venue.

Invitations

On the 6th July 2015 a 'Save the Date' email was sent to delegates to notify them of the upcoming event. On the 5th August 2015 the invitation was sent out which confirmed the venue and outline for the two events. The approved invitation was sent to 308 individuals which included those that attended on the 6th March 2015 but also responded to the DG

CLIMA consultation (mailing list sent on the 26th June 2015) and provided email addresses. The deadline for registration was set as 2nd September 2015 as the venue required final numbers by 4th September 2015.

Ricardo-AEA used the same secure online web–based system for bookings and management of the workshop events as the first workshop. However the website address was changed to: http://ag-lulucf-2030.aeasolutions.co.uk/ user name: AGLULUCF and password: Workshop. Delegates were able to register for one day or both. See appendix 1 for a copy of the invitation sent on the 05th August. We also asked delegates to select their preferred breakout group.

Each delegate was asked to provide up to 50 words about their main fields of interest/ expertise during the registration process along with any dietary requirements. On registration delegates received an automatic confirmation email with further details about the event and travel information

The first mailing resulted in 43 registrations within a few days. This large number of registration was perhaps aided by the 'save the date' email and there was another steep increase when a reminder was sent on 1st September. This pattern is perfectly normal as delegates often need to see the invitation more than once before they take action or need time to seek approval from their budget holder for time and travel. Regular reports were supplied to the EC on the number of registrations to date.

Below is a table showing the steady increase:

Week Starting	Number Registered
3rd August	43
10th August	15
17th August	21
24th August	22
31st August	57
7th September	5
Total	163*

** It was agreed to register more delegates than spaces to allow for a small percentage of 'no shows' on the day.*

We also had a few individuals who did not register using the online registration but sent an email direct or turned up on the day.

On Monday 7th September registered delegates received an email reminding them about the event, together with a list of the registered delegates to date with their interest/expertise and the final agenda (see Appendix 2 for a copy of this email). Accommodation for delegates was not arranged but a list of hotels was provided.

Format of the Event

The first day of the two-day programme was to inform representatives from Member States and other stakeholders of the outcome of the recent DG CLIMA Consultation on addressing greenhouse gas emissions from agriculture and LULUCF in the context of the 2030 EU climate and energy framework. Participants were invited to deepen and debate views expressed in the submissions, in the presence of policy officials of the Commission. Registration opened at 09:30 hrs and the session commenced promptly at 10:30 hrs. There was an opportunity for networking at during lunch and coffee breaks, and a drinks reception with canapés after the event for approximately one hour at the Royal Windsor Hotel.

The second day was a technical workshop that reported back from recent studies reviewing the effective implementation of climate action in the agriculture and forestry sectors. Registration begin at 08:30 with coffee, with the session starting at 09:00 hrs. The focus of the workshop was to move beyond the consultation and, using information from recent studies undertaken by the Commission, provide insight into climate action state of the art and best practice in the agriculture and forestry sectors.

The events were also an opportunity to:

- Share new information.
- Challenge current thinking.
- Exchange ideas.
- Increase awareness and understanding.
- Provide opportunities for networking.

The format of the two-day event included presentations and breakout sessions. The final agenda was as follows:

Monday 14th September 2015

09.30	**Registration, coffee**	
10.30 Plenary	**Session 1: Refining the understanding of stakeholder issues** **Chair: Prof Richard Wakeford, Visiting Professor, Birmingham City University**	
	Welcome and Introduction to the event	Artur Runge-Metzger Director DG CLIMA
	Overview of stakeholder responses: the key issues	Peter Wehrheim, Head of Unit DG CLIMA
	Clarification Questions and answers to presentations	
11.00	**Panel discussion: Facilitator: Prof Richard Wakeford**	**Representatives**
	Topics: • Agriculture and land issues – implication for farming • Forestry and LULUCF; optimising use of a national resource • Biomass and soils: the importance of carbon pools for EU climate policy in preserving ambition • Bioeconomy: facilitating the use of a non-fossil resource	Pekka Pesonen, Dir General COPA-COGECA Piotr Borkowski, Exec Dir EUSTAFOR Dr Aljoscha Requardt, Sec General CEPF Pieter De Pous, Policy Director EEB Marco Mensink, Dir General CEPI Jan Stambasky, President European Biogas Association
	Questions and answers to panel from the floor	
12.30	**Session 2: Summaries by the Commission**	

	The EU's climate policy framework and agriculture, forestry and other land uses	Yvon Slingenberg, Cabinet Commissioner Arias Cañete
	Assessing the multiple objectives of agriculture, forestry and other land uses	Mihail Dumitru Dep. Director General , DG AGRI

13.00 – 14.30 Buffet Lunch (arranged on the premises)

14.30	**Session 3: Enriching stakeholder inputs: break-out sessions** **Facilitator: Hugh Martineau and J Webb - Ricardo-AEA** **Clunie Keenleyside and Kaley Hart - IEEP**	
	Refining understanding of stakeholder issues – general session for all participants	Introduction: DG CLIMA Contractor
Breakout groups **(1h45mins)**	Detail on views on how to balance incentive for climate actions, environmental integrity and cost-effectiveness, based upon stakeholder paper questions and policy options: • Reporting versus accounting – up-dating the rules • Implementing flexibilities and environmental integrity • Sharing the burden between Member States • Barriers to implementation, administrative costs and effort	Four breakout groups[14] Opportunity for all participants to discuss each of the points
16.30	Coffee Break	
17.00	**Session 4: Summary of the day** **Chair: Prof Richard Wakeford**	
	Feedback from breakout sessions	Rapporteurs (DG CLIMA and DG AGRI)
	Closing statements	Aldo Longo, Director, DG AGRI and Jos Delbeke, Director General DG CLIMA
End 18.00	**Drinks Reception**	

[14] Breakout groups: 1) Cropland/grassland/peatlands/soil and nutrient management, 2) Livestock systems 3) Forest management, 4) Agricultural and forest Biomass/Energy/Industry nexus

Tuesday 15th September

Plenary	**Chair: Prof Richard Wakeford**	
08.30	Registration, coffee	
9.00 – 9.15	Introduction to the day and outlining the way forward	Artur Runge-Metzger Director DG CLIMA A
9.15	Success stories and best practices climate action in agriculture and forestry	Ana Frelih-Larsen Ecologic Institute (contractor)
	Questions and answers to presenters from the floor	
10.30	**Coffee Break**	
11.00	Mitigation potential in Agriculture and LULUCF – state of the art	Hugh Martineau Ricardo-AEA/ Kaley Hart IEEP (Contractor)
	Questions and answers to presenters from the floor	
11.50	Summary and close	Artur Runge-Metzger Director, DG CLIMA-A
12.00pm	Lunch, networking	

The presentations slides are in Appendix 3 from:

- Peter Wehrheim DG CLIMA Introduction 14th September
- Summary slides from the breakout session on the 14th September
- Introduction from DG CLIMA on 15th September 2015
- Ana Frelih-Larsen Ecologic Institute on 15th September
- Ricardo-AEA & IEEP on the 15th September

Break-out Session

The breakout session was discussed thoroughly with the European Commission in the weeks leading up to the workshop. It was agreed that the overall objective of the break-out session was too:

- Gather information to assist and inform the ranking of climate actions
    - How relevant are actions to sectors and geographic areas
- To discuss the practicalities of scaling up or implementation new of actions from those identified
    - To what degree actions are already implemented through CAP
    - How can they be improved
    - What actions should be considered in the future and what are the implications for affected groups

The breakout sessions was interactive and intended to generate useful discussion relating to the implementation of actions. The delegates were split into four groups prior to the workshop:

1. Cropland/grassland/peatlands/soil and nutrient management

2. Livestock systems
3. Forest management
4. Agricultural and forest Biomass/Energy/Industry nexus

For more details about the outcomes from the breakout sessions please see section 3.

Badges and Delegate Packs

Ricardo-AEA provided delegate badges, printed the agenda, participant list and event feedback questionnaire.

On the Day Event Management

For both days the workshop was attended by 3 members of the Ricardo-AEA team: two technical team members and an event manager. From IEEP there were two technical team members. On the second day a third IEEP team member attended.

Ricardo-AEA ensured the rooms were set up with the correct equipment; prepared the registration area, registered delegates, distributed the delegate folder and badges. On the first day 152 delegates attended (20 no shows but we had 11 turn up on the day). For the second day delegates did not need to re-register however approx. 12 badges were returned after day 1 and 3 new people did arrived.

The delegates were from the following countries:

(The full list of attendees is in Appendix 4).

Country	No of delegates	Country	No of delegates	Country	No of delegates
Austria	3	Germany	6	Norway	1
Belgium	61	Hungary	3	Poland	5
Cyprus	1	Ireland	7	Romania	3
Czech Republic	3	Italy	1	Spain	1
Denmark	7	Latvia	3	Sweden	8
Estonia	2	Lithuania	2	Switzerland	2
Finland	3	Luxembourg	1	UK	13
France	6	Malta	2		

It is no surprise that the host country had the largest number of attendees i.e. Belgium 61.

The speaker's final presentations were converted to PDF and uploaded to the online registration website in a single ZIP file. See Figure 3.

At the end of the event, Ricardo-AEA logged any amended details provided by delegates.

After the workshops

Thank you emails were sent to the participants on Thursday 17th September. Along with informing participants of the availability to download the presentations from the registration website. There was also a reminder to complete the feedback form. For those that did not manage to attend, a link to the presentations was provided for information.

Breakout Groups

The purpose of the breakout was to gather information and discuss the practicalities. Below is a summary from each of the four breakout groups which was presented as slides to the plenary session that followed the breakout sessions.

Group 1 Cropland/grassland/peatlands/soil and nutrient management

Implementing flexibilities and environmental integrity

- *Channel carbon between Member States; will provide assurance of reaching target*
- *But also fear that it will soften ESD compliance from some*

Barriers to implementation, administrative costs and effort

- *Avoid perverse incentives from other policies*
- *Relate not only about mitigation, we should add in adaptation and productivity onto the discussion*
- *Feedback to farmers needs enhancement*

Sharing the burden between Member States

- *GDP per capita only not appropriate for LULUCF*
- *Technical potential, marginal costs, local importance of the sector as a basis for decisions*

Reporting versus accounting – up- dating the rules

- *Inter-annual variation – techniques to be improved, accounting within period*
- *Choice of base year non-controversial*

Group 2 Livestock systems

Implementing flexibilities and environmental integrity

- *Cost effectiveness should be taken into account*
- *Agriculture non-CO2 "more reliable" than LULUCF*

Barriers to implementation, administrative costs and effort

- *Lack of [the right] incentives*
- *Need for more research – tech transfer*

Sharing the burden between Member States

- *Need for "level playing field" regulation*
- *Better use of existing regulation*

Reporting versus accounting – up- dating the rules

- *Need for good inventories to pick up efforts*
- *Value of good data for accurate reporting and accounting*

Group 3 Forest management

Implementing flexibilities and environmental integrity

- *Ranged from unlimited to flexibility as a threat*
- *SFM should be a starting point*
- *Strongly linked to accounting*

Barriers to implementation, administrative costs and effort

- Tech. capacity for projections, data availability
- Ownership structure, importance of communication
- Long term cycles – 2050 LULUCF [needed]

Sharing the burden between Member States

- *FMRL should create level playing field*
- *Opposing situation re: Af/De-forestation*

Reporting versus accounting – up- dating the rules

- *Some agreement on simplifying rules and having land based accounting*
- *Some support to keep some +ve aspects of Kyoto*

Group 4 Agricultural and forest Biomass/Energy /Industry nexus

Implementing flexibilities and environmental integrity

- *Use of a CAP is an option (or a threshold)*
- *Credits and debits are in different sectors for bioenergy*

Barriers to implementation, administrative costs and effort

- *Monitoring and control – complex*
- *Imports exports – competitiveness, accounting issues*
- *Lack of EU competence can be barrier*

Sharing the burden between Member States

- *Appreciation for intensity in the burden sharing*
- *Uneven distribution of natural potential*

Reporting versus accounting – up- dating the rules

- *Agricultural Land – OK (net-net)*
- *However, questions on FMRL, and ARD*
- *HWP needs to be taken into accounting*

Delegates Feedback

Introduction

Ricardo-AEA developed a feedback questionnaire to assess whether attendees found value in the workshop (see Appendix 5). The questionnaire gathered information on:

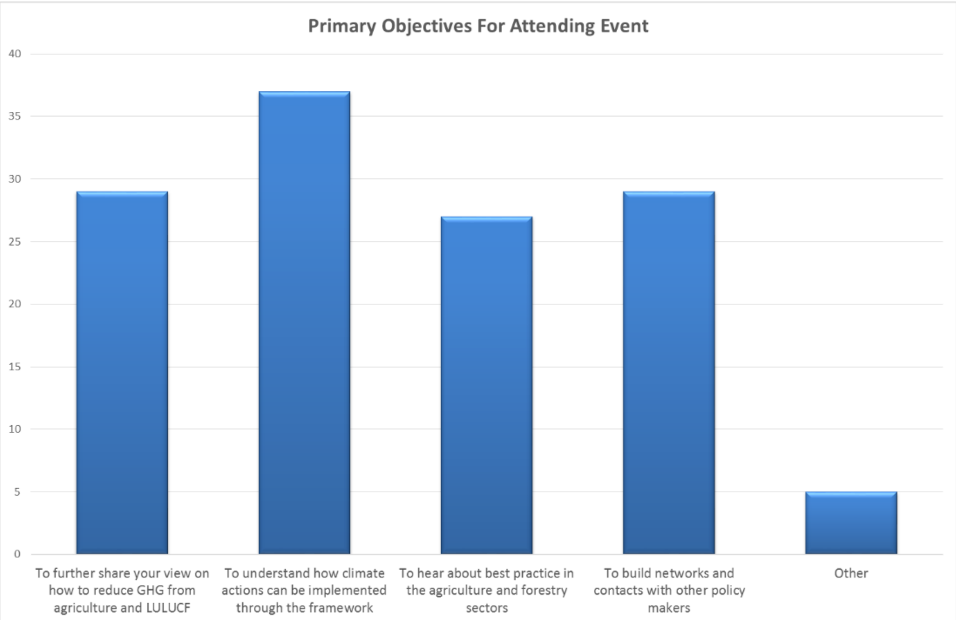
- Participant characteristics;
- Objectives for attending;
- Reactions to the presentations and breakout sessions;
- Aspects that were particularly valuable and areas for improvement;
- Event organisation;
- Any additional comments.

Delegates were reminded about the importance of completing the questionnaire and were also sent a copy with the thank you email, for those that did not complete it on the day. This section of the report will provide the statistical analysis of the responses in the form of percentages, graphics and feedback on the open-ended questions. All the raw data has been sent to the EC for their own files.

Feedback

49 delegates completed a feedback form which representative 32% of the total delegates. Of the 49 people that completed a questionnaire, 37 were policy officers, 2 were technical experts, 5 were researchers and 5 delegates classed themselves as ‘other’ which included Head of Unit, Deputy MD, Secretary General, Sustainable Manager and Communications Team. All 49 responders of the questionnaire attended both days.

Delegates were asked their objectives for attending the workshop. A higher number of delegates wished to understand how climate actions can be implemented through the framework (37) and of equal importance was to further share your view on how to reduce GHG from agriculture and LULUCF and to build networks and contacts with other policy makers (both 29).



(Please note that most delegates selected more than one answer)

Five delegate indicated their ‘other’ reason for attending:

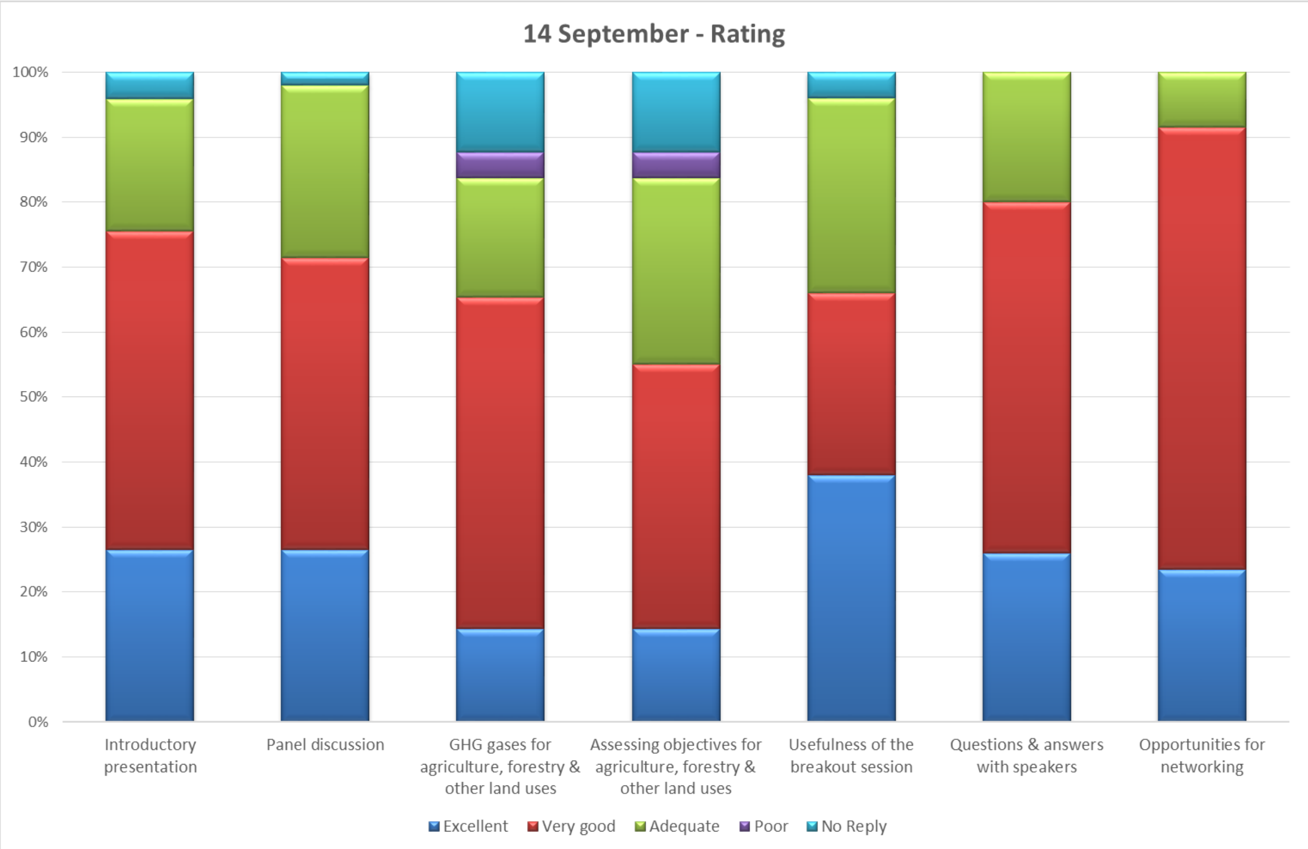
- To have analysis of the questions to the consultation.
- Details on the future proposal from the Commission.
- To hear other stakeholders views on LULUCF in 2030.
- Understand the issues of 2030 LULUCF accounting.
- Provide some contribution on mitigating options provided by the livestock production sector.

Delegates were asked whether their objectives for attending the workshop had been met and the results were:

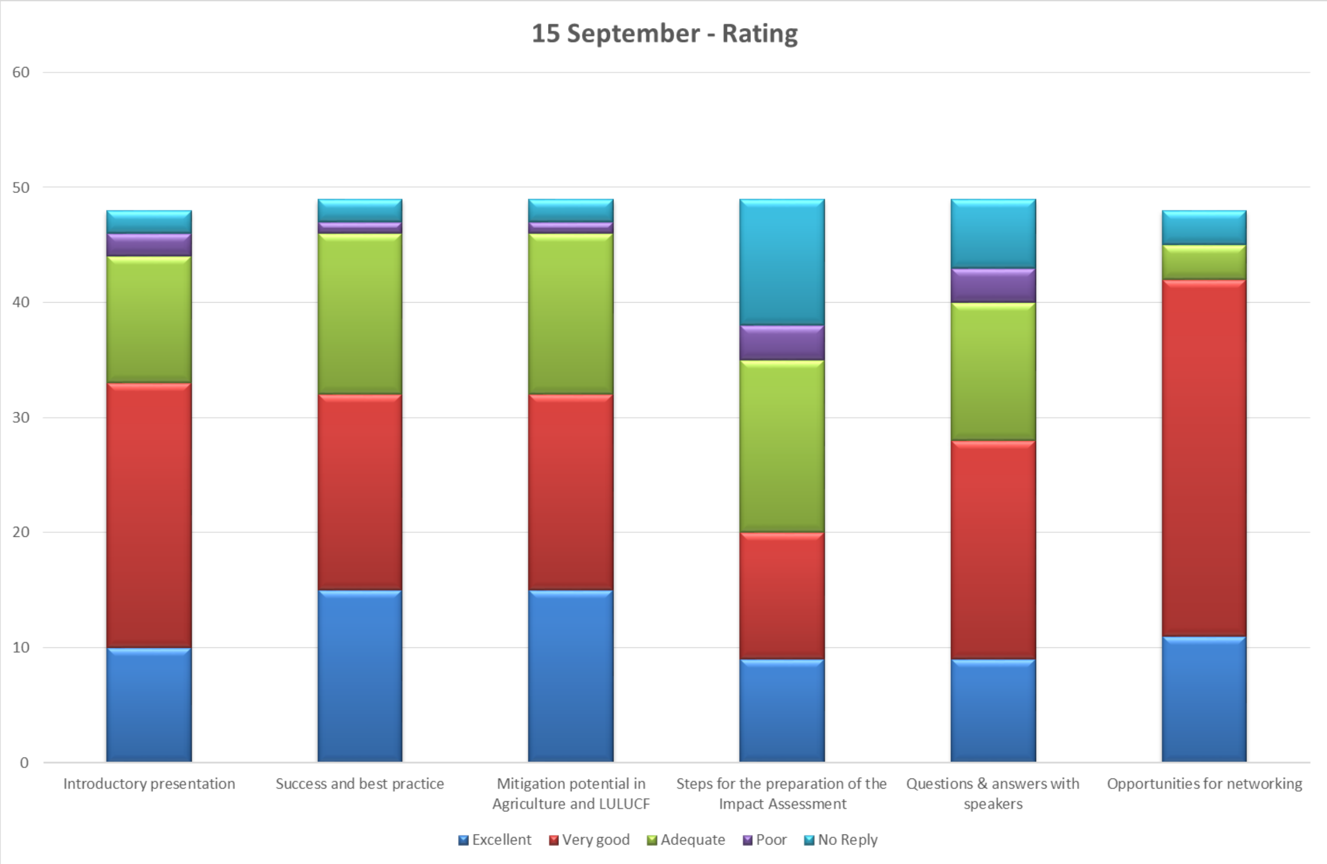
Did the event meet your objectives?	Number	Percentage
Yes, fully	21	43
Yes, partially	27	55
No	1	2

The delegate who stated 'no' gave the following reason: "No, only 1 slide on the analysis of the consultation".

Delegates were asked to rate the presentations and breakouts for the two separate days. For day one the highest proportion of 'excellent' rating was for opportunities for networking and the usefulness of the breakout sessions. The opportunity to ask questions to the speakers was also well received with 35 stating excellent or very good.



For day two the opportunities for networking was rated as excellent or very good by 42 of those who responded. The presentation on best practice by Ecologic Institute was rated excellent or very good by 32 delegates.



A range of answers was given for what aspects of the workshop had been most valuable. Below is a sample as many express similar themes i.e. good networking and presentations and workshop interaction:

- Panel discussion.
- Link of LULUCF with ecological focus areas.
- Networking with experts outside of Brussels allows for more creative brainstorming.
- The discussion of issues in implementation of agriculture and LULUCF in EU2030 targets, as well as wide information on mitigation options currently under development.
- The presentations of a wide range of stakeholder views on common problems.
- Accounting discussion where interesting as we do not have any experience in accounting. Also the best practices were interesting.
- Mutual understanding including MS specification and EU studies.
- Opportunity to hear views & inputs of others through Q&A sessions. Presentations very interesting - useful to have slides made available.
- Broad participation of specialists with different backgrounds, member states, policy etc.

A broad range of responses was given to how future workshops could be improved. The below is the full list of suggestions and they have been grouped into themes:

General

- With a platform online in time with forum and presentations and comments. A free and online box for suggestions/ideas for implementation of legislation.
- It would be useful to get a little bit of accurate EC position about plans to implement policies and then possibility to discuss its programme together.
- A summary of what the current LULUCF methodology entails.
- Involve representatives of member states as speakers or panellists.

Breakouts

- More roundtable discussion and more breakout groups. Improve the exchange of ideas and co-operative work.
- State in the invitation that the goal for breakout groups is offering solutions, so that people don't expect a more informative presentation.
- More discussion on solutions.
- Perhaps more discussion time. At least 3 of the 4 breakout sessions were of interest - but I may be unusual as I am Spanish LULUCF and energy.

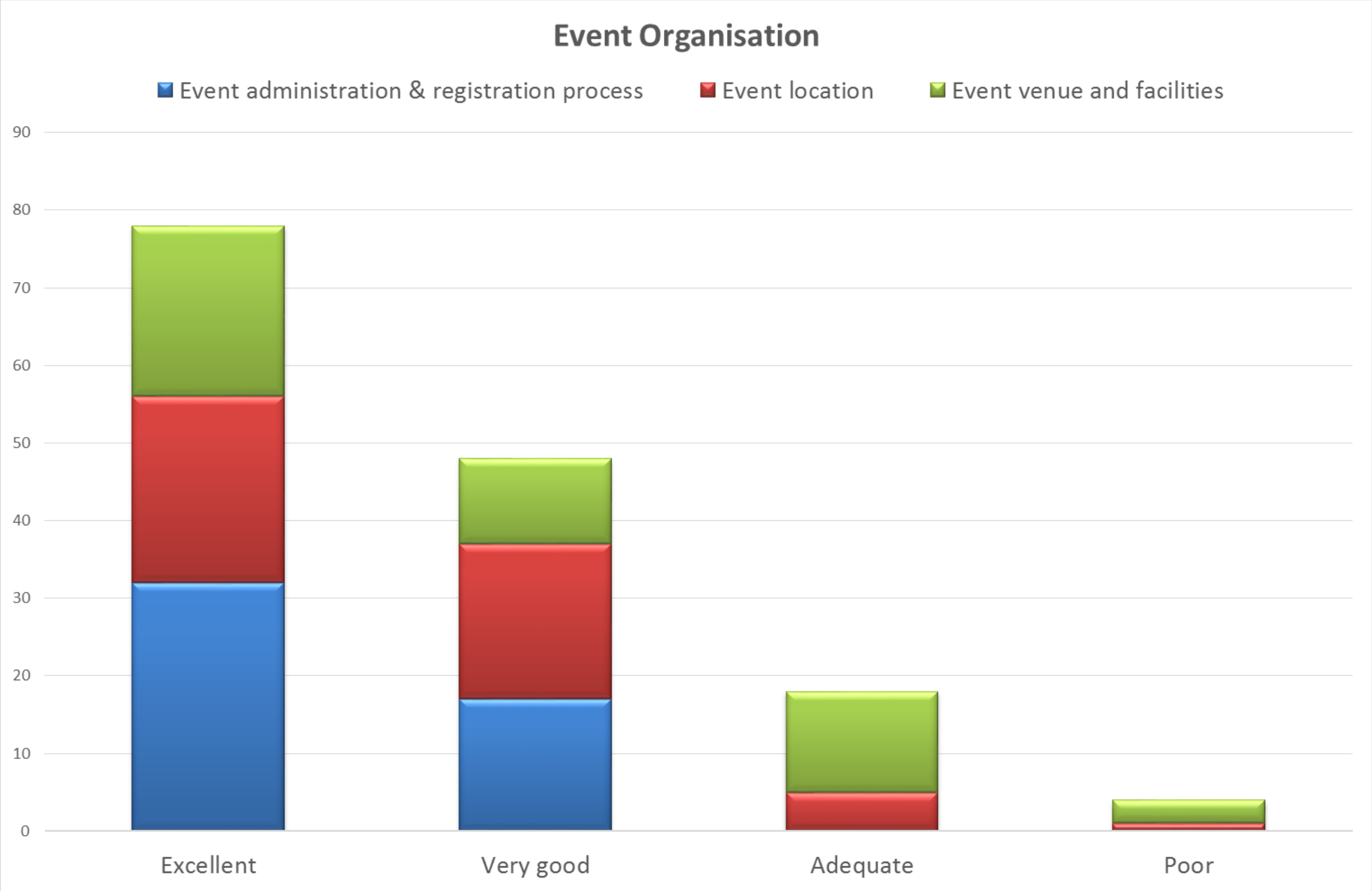
Presentations

- More presentations are new concepts/solutions would be have been useful to further discussions on the 1st day. It was interesting to hear panels' views but didn't provide significant new information from the consultation responses.
- More specific case studies in particular from the south/med region.
- Would have been interesting to have a more detailed presentation of views expressed in the stakeholder consultation.
- We did not properly address the needs of Agri/Forestry to support the bio economy. It seemed to be mostly about the sectors in isolation - Nevertheless - still worthwhile.
- More analysis of the answers of the consultation.
- More summaries on the consultation responses.
- More insights into the results of the stakeholder consultation would be been interesting.
- Information from projects (Tuesday) should be broader. Not only the own projects from the organisers.

Logistics and Venue

- Just to plan other similar events.
- Send all presentation in advance - if possible link to reports.
- Better screen and paper copies of presentations.
- Distribute presentations before the event.
- Presentations on screen difficult to see.
- There were limited options to see the screen (small but an annoying thing).
- By having a stage for panellists, difficult to hear and see.
- Better air-conditioning, better view of presentation, better seats.
- Venue was quite small and hot.
- More space for bringing good practice documents.
- Try to organize the event as a zero-emissions-event (-> travelling, catering, video-conference, compensation…).

Feedback on the logistics was very positive, with respondents thinking that they were excellent or very good. Just one individual who was from Germany felt that the location of Brussels was poor and three felt the event venue and facilities was also poor.



Below are all the additional comments that were received:

Monday 14th September

- Congratulations.
- Useful to exchange between Member States and stakeholders but no real discussion with Clima on the impact assessments and the proposal.
- Breakout groups included some good ideas expressed in the consultation. The consultation assessment report should/could have been made available in advance, to allow more debate. Some issues, as views of the Commission on the units, would have been interesting to address.
- Those leading the working groups should have more knowledge on the subject otherwise we can stay too general and/or get easily off topic.
- The structure and chairing worked well. Timekeeping was good. The facilitators in the breakout group's sessions was effective in stimulating debate.
- It was well organised and well instructed. Interesting experience in the breakout sessions. Presenters were great.
- The first panel meeting was excellent. The meeting was opened with a good opportunity for group discussions. I would have liked smaller group discussion supporting networking and the essential need to understand other people's point of view.
- I expected more workshop. Too little attention on the effects of climate change on the LULUCF sector and the consequences for the future regulation scheme. Adaption of LULUCF (especially forests and forestry) is crucial for - hopefully - keeping the present level of mitigation effects.
- Difficult to see PowerPoint.
- More analysis of the consultation would have been helpful. More explicit discussions of pros and cons of the options - especially considering the international perspectives and implications for the post-legislation process.

- Thanks a lot. Looking forward to have bilateral discussion (FR-Commission) about simplifying accounting, reducing uncertainty, increasing credibility. In depth discussions still necessary.
- Many presentations too much information / not readable & not visible from the back rows - should have been circulated in advance. Too little focus & discussion on potential / alternative set-ups for integration of LULUCF - that is: integration of LULUCF into the non-ETS an implicit & foregone conclusion.
- Could not see the text at the bottom of the screen.
- Good balance of presentations and panel discussions. Good flexibility by workshop panellists and key speakers. Surprised no more quantitative analysis of consultation responses. The list of participants was printed in small font (have to use 2 pairs of glasses to read).
- This event's objectives was to inform the EC and brainstorm. The downside was that some stakeholders come to disseminate their own messages and not to contribute to the objectives or reducing GHG emissions in Agri and LULUCF. Good Q&A sessions.
- ATF is open to provide further expertise on livestock production mitigation options, that we consider very promising. Please contact florence.macherez@animaltaskforce.eu. ATF is a public private European Platform bringing together research institutions, industries and farmers to work on sustainable & competitive livestock production sector in Europe.
- Good moderation. Use of humour helped keep the energy in the room.
- Presentations by DG Agri/Clima could have been nice to open the meeting.
- I believe that we need more events like this one where DG Clima and DG Agri collaborate together on such important themes.
- It was a bit unfortunate that from the back rows it was not possible to see the speakers at the panel discussion. A raised platform would have been helpful.

Tuesday 15th September

- Interesting but not directly linked to 2030 questions that we need to answer. Can be more useful for implementation on the national level. Lack of informal from CION on the way forward to answer para 2-14 of the council conclusion.
- I would have left more time for discussion to go through the results of the mitigation potential analysis.
- More opportunity/time for discussion would have been useful.
- Presenters where really good in giving out real practice experience.
- This day was excellent. I might have put this day first and added other briefings on elements of this complex policy and technology.
- I expected more <u>work</u>shop. Too little attention <u>on</u> the high potential of farmers, forest owners and rural areas for energy production. (Maybe these aren't really LULUCF-measure as UN defines it, but they are done by LULUCF-actors. Furthermore high synergies are possible.)
- More focus on agriculture and the CAP, agenda for forestry, wood use etc. - as not much discussed.
- Good presentations. Unclear when the Ricardo report will be available.
- Make the presentations/publications available please for reading further. Thanks for organising.
- I would like more examples on best practice to be shared.
- Very good event. Thank you very much!

Appendices

Appendix 1 - Invitation

Dear (Personalised with the First Name)

Agriculture and LULUCF in 2030 EU Climate and Energy Framework:

Review of Stakeholder responses to the Agriculture and LULUCF Consultation

Conference: 14th September 2015

Further to my email on the 06 July 2015, I am writing to confirm that registration is now open for the conference on the review of Stakeholder responses to the Agriculture and LULUCF Consultation.

The event will inform representatives from Member States and other stakeholders of the outcome of the recent *Consultation on addressing greenhouse gas emissions from agriculture and LULUCF in the context of the 2030 EU climate and energy framework* Participants will be invited to deepen and debate views expressed in the submissions, in the presence of policy officials of the Commission.

The workshop is free to attend and will take place in Royal Windsor Hotel, Rue Duquesnoy 5, 1000 Ville de Bruxelles on Monday 14 September 2015. Registration will start at 09:30 hrs and the session will commence promptly at 10:30 hrs. There will be an opportunity for networking at during lunch and coffee breaks, and a drinks reception with canapés at after the event 18:00 hrs for approximately one hour at the Royal Windsor Hotel.

Agriculture and LULUCF in 2030 EU Climate and Energy Framework:

State of the art and best practice for climate action in the agriculture and forestry sectors

Workshop: 15th September 2015

The Stakeholder conference will be followed by a technical workshop that will report back from recent studies reviewing the effective implementation of climate action in the agriculture and forestry sectors. Registration will begin at 08:30 with coffee, with the session starting at 09:00 hrs. The focus of the workshop will move beyond the consultation and, using information from recent studies undertaken by the Commission, provide insight into climate action state of the art and best practice in the agriculture and forestry sectors. The workshop will end at approximately 12:00 hrs when lunch will be served and you are very welcome to continue networking with other participants until 15:00 hrs.

As an important stakeholder in this policy area we would like to invite you, or an alternative representative from your organisation, to attend both the stakeholder conference and the workshop.

Please register online by **Wednesday 02 September 2015** using the user name 'AGLULUCF' and the password 'Workshop'.

Please identify on the form:

- Which (or both) of the events you will register for;
- Which breakout group would be of most interest to you on the registration form i.e.
  1. Cropland/grassland/peatlands/soil and nutrient management
  2. Livestock systems

3. Forest management
4. Agricultural and forest Biomass/Energy/Industry nexus

Although please note that we will need to balance the group numbers so we cannot guarantee your preferred choice.

A detailed agenda and supporting papers will be sent prior to the workshop.

The presentations will be in English with no translation facilities. Please note that, while participation is free, for organisational reasons the stakeholder conference and the workshop will be restricted to 150 delegates on each day.

If you have any questions or need any additional information, please feel free to contact me by telephone +44 1235 753291 or email Jemma.Howland@ricardo-aea.com.

We look forward to welcoming you in Brussels.

Kind regards,

Jemma Howland

Workshop Co-ordinator

To recap:

Registration form: http://ag-lulucf-2030.aeasolutions.co.uk/

User name: AGLULUCF

Password: Workshop

RICARDO-AEA

Ricardo-AEA, Gemini Building, Fermi Avenue, Harwell, Oxon, OX11 0QR
Tel: +44 (0) 1235 753291 | E-mail: Jemma.Howland@ricardo-aea.com | Web: www.ricardo-aea.com

Appendix 2 – Final confirmation to delegates

* Important Final Information *

Agriculture and LULUCF in 2030 EU Climate and Energy Framework:

Review of Stakeholder responses to the Agriculture and LULUCF Consultation

Conference: 14th September 2015

State of the art and best practice for climate action in the agriculture and forestry sectors

Workshop: 15th September 2015

Dear Colleague

Thank you very much for registering for one or both of the above events.

As a reminder the first event will be on the 14th September will take place in Royal Windsor Hotel, Rue Duquesnoy 5, 1000 Ville de Bruxelles (travel instructions below). Registration will start at 09:30 hrs and the session will commence promptly at 10:30 hrs. There will be an opportunity for networking at during lunch and coffee breaks, and a drinks reception with canapés at after the event 18:00 hrs for approximately one hour at the Royal Windsor Hotel.

The Stakeholder conference on the 15th September will be a technical workshop that will report back from recent studies reviewing the effective implementation of climate action in the agriculture and forestry sectors. Registration will begin at 08:30 with coffee, with the session starting at 09:00 hrs. The focus of the workshop will move beyond the consultation and, using information from recent studies undertaken by the Commission, provide insight into climate action state of the art and best practice in the agriculture and forestry sectors. The workshop will end at approximately 12:00 hrs when lunch will be served and you are very welcome to continue networking with other participants until 15:00 hrs.

The final agenda and a list of participants, with biographies, are attached. We are not intending to hand out paper copies of the presentations, but we do plan to upload these onto the registration website after the event at http://ag-lulucf-2030.aeasolutions.co.uk using the user name 'AGLULUCF' and the password 'Workshop'.

If you are now unable to attend the event or wish to send a substitute, please let me know as soon as possible by email. Or, if you have any issues on the day, please contact me direct by telephone on +44 (0) 7968 707492 or email jemma.howland@ricardo.com.

We look forward to seeing you next week.

Kind regards

Jemma Howland

Workshop Co-ordinator

Travel and Accommodation Instructions

The location of the Royal Windsor Hotel is 5 Rue Duquesnoy, 1000 Brussels, Belgium.

The hotel website is http://www.warwickhotels.com/royal-windsor Travel directions can be accessed on the hotel website here and a map can be accessed here.

Airport

Brussels National Airport is approximately 14km from the hotel and there is a direct train connection from the airport to Central Station which is a short walk to the hotel. Please use the train/metro or bus/tram instructions below.

Train/Metro

The hotel is a short walk from the Central Station (Gare Centrale). This station has direct connections to South Stations such as Brussels Midi Station (Gare du Midi) which has Thalys, TGV and Eurostar terminals. From the Midi Station to the Central Station the simplest route is to take the Thalys train which has a direct connection and takes around 2 minutes. If travelling on the Metro the Central station is on lines 1 and 5.

Bus/Tram

Central Station is the closet bus station to the hotel and is accessible on bus lines 29, 38, 48, 63, 65, 66, 71 and Royal line 95. Central station is accessible on Tram Bourse lines 3 & 4 and Royal lines 92 & 94. Central station can be reached from Luxembourg Station on bus route 38 (Direction Debrouckère). If travelling from Brussels North Station (Gare de Bruxelles-Nord) Tram lines 3 or 4 should be used (Direction Stalle) to Bourse which is a 5 minute by walk to the hotel.

Taxi

Taking a taxi in Brussels is quite straight forward if you are in the city centre. There are many taxi stands on the side of the main streets or you can wave a taxi if it is more than 100 metres from a taxi stand. All taxis are metered and you do not need to tip, although rounding up to the nearest euro is sometimes acceptable. Fares are approx. €2.40 flag-fall and €1.35 per km. A €2 surcharge applies between 10pm and 6am. We do not recommend you take a taxi from drivers offering you a ride (inside or directly outside the airport). Just go to the official taxi queue directly outside the airport. Paying by credit card is not possible in all taxis, so make sure you ask first.

Driving

There is parking available at the hotel (for an additional cost) and parking is also available at Grand Place which is 3.6km from the hotel. The Grand Place website can be accessed here.

Please note that from 29 June 2015 the Rue Duquesnoy will be a one-way street from Place de la Madeleine to Place Saint Jean.

Accommodation

Accommodation has not been arranged for participants at the Royal Windsor, however, if you wish to stay overnight please contact the hotel direct. Below are some other local hotels (please note these do not come with personal recommendation):

- Hotel ibis Brussels off Grand Place - http://www.ibis.com/gb/hotel-1046-ibis-brussels-off-grand-place/index.shtml
- Hotel Aris - http://www.arishotel.be
- Hotel NH Brussels Carrefour de l'Europe - http://www.nh-hotels.com/hotel/nh-brussels-carrefour-de-l-europe
- Hotel La Madeleine - http://www.hotel-la-madeleine.be

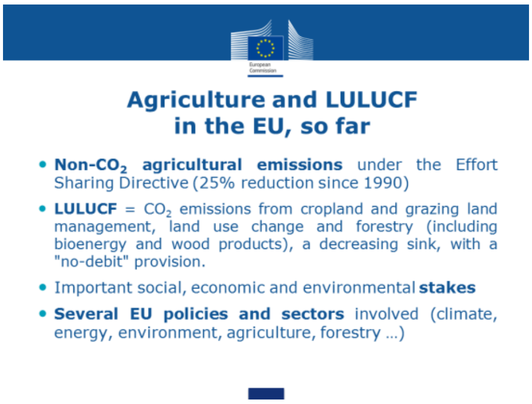
- Hotel Le Dixseptième - http://www.ledixseptieme.be
- Hotel Alma - http://www.almahotel.be
- Hotel Mozart - http://www.hotel-mozart.be

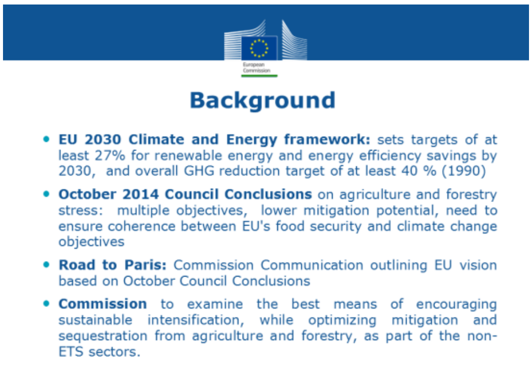
RICARDO-AEA

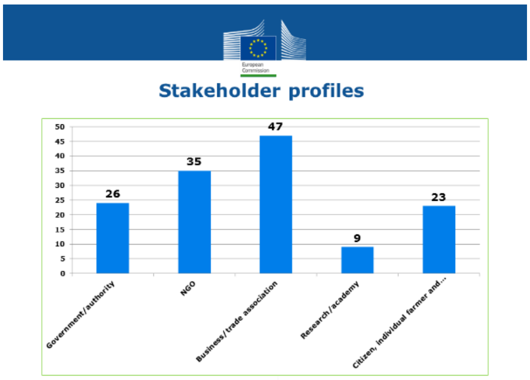
Ricardo-AEA, Gemini Building, Fermi Avenue, Harwell, Oxon, OX11 0QR
Tel: +44 (0) 1235 753291 | E-mail: Jemma.Howland@ricardo-aea.com | Web: www.ricardo-aea.com

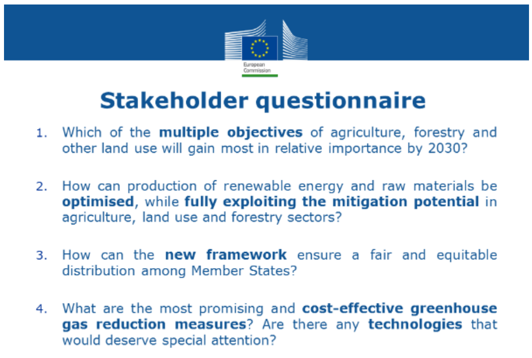
Appendix 3 – Presentation Slides

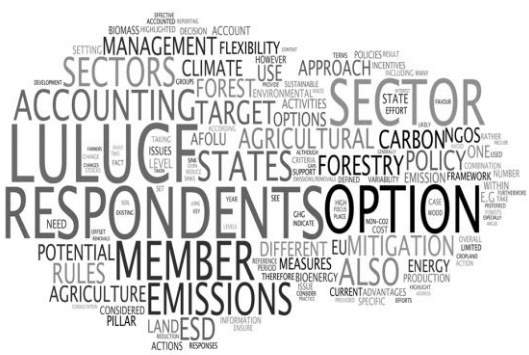
Peter Wehrheim DG CLIMA Introduction 14th September











Feedback from Member States (1)

- Almost all answers emphasize the **geographical, biophysical etc. differences** among MS that are considered more significant in agriculture, land use and forestry than in other sectors
- **Accounting is** seen as **key** by many. Broad satisfaction with current rules, often openness to discuss improvements (e.g. land-based accounting, base years)
- **Flexibility** is supported, but some concerns about ambition

Feedback from Member States (2)

- **Forest management Reference Levels:** seen as reasonable approach by most Member States
- **Lower mitigation potential** in agriculture and land use
- **On agriculture** many Member States refer to the CAP/EU policies as the necessary source to incentivize climate action

Feedback from Industry

- **Producer stakeholders** express the opinion that strong regulation on efficient countries would be "unfair".
- **Food and energy** expected to increase by 2030.
- **Active forest management**, increased mobilisation, better nutrient management seen as ways to improve mitigation, but need support.
- **Agriculture:** National circumstances important.
- **Forest producers** express concerns related to competitiveness and lack of incentives for additional mitigation action

Feedback from NGOs

- As most important objectives, the **conservation of carbon stocks, biodiversity and enhanced mitigation** are often mentioned
- **Increased bioenergy/biomass** use is a concern; some urge stronger sustainability criteria
- **CAP**: according to some, it doesn't provide sufficient incentives for mitigation
- **Flexibility:** often concerned about flexibility between LULUCF and other sectors, could weaken emission reduction efforts in other sectors

On options:

- Some respondents chose an Option but specified the conditions under which they would consider the Option truly acceptable.
- In fact, for all options, the specific rules, as yet not specified, on flexibility, accounting and target setting will influence any advantages and disadvantages they may have

Next steps

- **Summary report** will be part of an Impact Assessment
- **Legislative proposal** to be considered in 2016

Thank you - and let's begin!

Summary slides from the breakout session on the 14th September

Breakout group summaries

Colour coded as:

- Cropland/grassland/soil group
- Biomass/bioenergy/bio-economy nexus group
- Forest management group
- Livestock group

Climate Action

Implementing flexibilities and environmental integrity

- *Channel carbon between Member States; will provide assurance of reaching target*
- *But also fear that it will soften ESD compliance from some*
- *Use of a CAP is an option (or a threshold)*
- *Credits and debits are in different sectors for bioenergy*
- *Ranged from unlimited to flexibility as a threat*
- *SFM should be a starting point*
- *Strongly linked to accounting*
- *Cost effectiveness should be taken into account*
- *Agriculture non-CO2 "more reliable" than LULUCF*

Climate Action

Barriers to implementation, administrative costs and effort

- *Avoid perverse incentives from other policies*
- *Relate not only about mitigation, we should add in adaptation and productivity onto the discussion*
- *Feedback to farmers needs enhancement*
- *Monitoring and control – complex*
- *Imports exports – competitiveness, accounting issues*
- *Lack of EU competence can be barrier*
- *Tech. capacity for projections, data availability*
- *Ownership structure, importance of communication*
- *Long term cycles – 2050 LULUCF [needed]*
- *Lack of [the right] incentives*
- *Need for more research – tech transfer*

Climate Action

Sharing the burden between Member States

- *GDP per capita only not appropriate for LULUCF*
- *Technical potential, marginal costs, local importance of the sector as a basis for decisions*
- *FMRL should create level playing field*
- *Opposing situation re: Af/De-forestation*
- *Appreciation for intensity in the burden sharing*
- *Uneven distribution of natural potential*
- *Need for "level playing field" regulation*
- *Better use of existing regulation*

Climate Action

Reporting versus accounting – up-dating the rules

- *Inter-annual variation – techniques to be improved, accounting within period*
- *Choice of base year non-controversial*
- *Some agreement on simplifying rules and having land based accounting*
- *Some support to keep some +ve aspects of Kyoto*
- *Agricultural Land – OK (net-net)*
- *However, questions on FMRL, and ARD*
- *HWP needs to be taken into accounting*
- *Need for good inventories to pick up efforts*
- *Value of good data for accurate reporting and accounting*

Climate Action

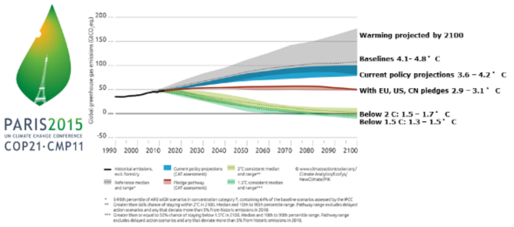
Introduction from DG CLIMA on 15th September 2015

State of the art and best practice for climate action in the agriculture and forestry sectors

Workshop "Agriculture and LULUCF in 2030 EU Climate and Energy Framework"
Brussels, 15 September 2015

What do we need the Agreement to deliver?

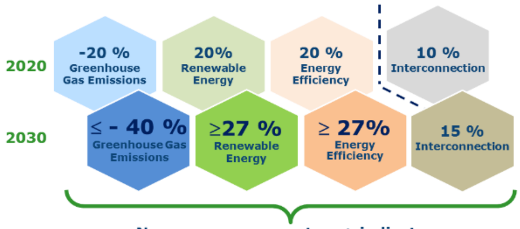
Staying below 2°C: global action 2020–2030 is critical



Source: Climate Action Tracker

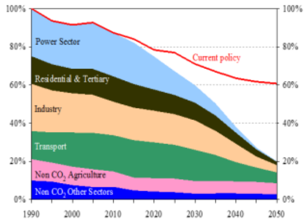
EU response

2030 Framework for Climate and Energy



Projection of EU agriculture non-CO2 emissions

- Agriculture and land based emissions will grow in relative importance
- By 2050: third of total EU emissions, tripling its current share



Policy context

- ***October 2014 European Council invites EC***
  - Propose policy on **how to include LULUCF** into the 2030 greenhouse gas mitigation framework;
  - Take into account the **multiple objectives**: food security and climate change mitigation
  - "Lower mitigation potential" of agriculture.
- ***Principles for the inclusion of LULUCF:***
  - **Build on rules already agreed** with Member States domestic LULUCF Decision adopted in 2013,
  - Making them fit for purpose for 2020 to 2030,
  - **No backsliding** in terms of environmental integrity; protect existing sinks; develop additional mitigation potential

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The way forward: next steps

- Two interlinked tracks for implementing the non-ETS 2030 framework
- Stakeholder consultation (March-June 2015) and stakeholder outreach meetings
- Impact Assessment:
  - **Analyse and compare the policy options;**
  - **Assess mitigation options for agriculture and forestry in each Member State;**
  - **Assess environmental integrity, economic and social impacts.**
- Legislative proposal in 2016.

Related questions raised in the stakeholder consultation

1. Which of the multiple objectives of the sectors will gain most in relative importance until 2030?
2. How can the new framework ensure a fair and equitable distribution of action for mitigation among Member States?
3. What are the most promising and cost-effective greenhouse gas reduction measures related to agriculture, forestry and other land uses?
4. What are the main obstacles and barriers to implement emission reduction measures?

Thank you!

Ana Frelih-Larsen Ecologic Institute on 15th September

SUCCESS STORIES AND BEST PRACTICES - CLIMATE ACTION IN AGRICULTURE AND FORESTRY

Ana Frelih-Larsen, Ecologic Institute
Brussels, 15 September 2015

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Study: Mainstreaming of climate change in rural development policy post 2013

DG Climate Action, 12/2013 – 09/2014

SRUC
THÜNEN
Solagro
INEA
AKI

http://bookshop.europa.eu/en/mainstreaming-climate-change-into-rural-development-policy-post-2013-pbML0614002/

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Technical guidance

- Fiches for 25 new and innovative climate actions
- Best practice LEADER projects and new concepts
- Combinations of rural development measures
- Cooperation activities

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Today's presentation

- Introduction to technical fiches
- Examples of technical actions and possible combinations of measures
- Joint activities / collective action among land owners and rural stakeholders

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Fiche Content

- An explanation of the mitigation / adaptation mechanism
- An example of how the action could be translated into an RDP operation.
- Guidance on the conditions likely to favour the operation.
- Guidance on the likely mitigation/adaptation effects, and any ancillary effects.
- Explanation of the main cost elements, indication of cost-effectiveness, any barriers.
- Underpinned by evidence.

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Selecting actions

- Mitigation solutions are complex, system- and region-specific, and impact also depends on actual management and skills
  - Examples are illustrative, non-exhaustive
  - Match the actions to regional & local conditions and needs

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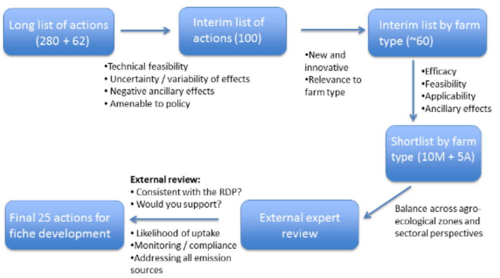
Selection process for fiche development



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	Mitigation Actions
M1	Extend the perennial phase of crop rotations
M2	Use of cover crops / reduced bare fallow
	Improve N efficiency
M4	Precise N application
M5	Biological N fixation in rotations and in grass mixes
M6	No-till
M7	Retain crop residues
M8	Loosen compacted soils / prevent soil compaction
	Restoration of wetlands
M10	Fat supplementation in ruminant diets
M11	Precision and multi-phase feeding
M12	Better livestock health planning
M13	Climate proofing planned investments
M14	Behavioural change towards better energy efficiency
M15	Solar fodder dryers
	Carbon audit

	Adaptation Actions
A1	Using adapted crops
A2	Use of cover crops /reduced bare fallow
A3	Soil erosion control plan
A4	Reduced tillage and zero tillage
A5	Optimising adaptation benefits of shelterbelts and hedges
A6	Optimising the adaptation benefits of land drainage
A7	Improving irrigation efficiency
A8	On farm harvesting and storage of rainwater
A9	Optimising greenhouse cultivation

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Carbon Audits

- Identify emissions and benchmark over time and against other farms
- Run scenarios to investigate impact and possible actions
- Results-oriented measure, allowing problem-solving, flexibility, and consideration of ancillary effects
- Barriers: data requirements, costs, time
- Examples: Cool Farm Tool, JRC carbon calculator

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Improve N efficiency

- A result-oriented approach providing payments when N-surpluses are reduced below a defined threshold
- Enables flexibility on how the reductions are achieved
- Average of 2 – 3 years to account for weather conditions
- Reduced N2O emissions, maintain yields, reduced N leaching, improved water quality
- Several examples in Germany: e.g. Lower-Saxony
- Combination with carbon audit and training

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Combinations of actions and RD measures

- To better address needs and target support
- Context specific, need a clear logic
- Combine complementary actions with synergies, and when individual impact would be limited in absence of combination (e.g. manure 'chain')
- Complex activities, changes at landscape level (e.g. wetland restoration)

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Restoration of wetlands

- Avoid drainage and restore natural water table in drained peatlands
- Strong mitigation and other environmental benefits
- Requires the integration of many different measures and cooperation of land-users
- Due to very high emissions per hectare on drained organic soils, the net effect even with some leakage is positive
- A land-use concept for the wetland and region in order to minimise leakage

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Combination of measures for wetland restoration

Studies to support the planning process

+

Investments for water management infrastructure, and land consolidation if necessary

+

Support for extensive land use (agri-env-climate)

+

Pilot projects to improve use of organic soils (e.g. paludiculture)

+

Training, advisory services and cooperation

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Collective action

- Potentially significant leverage effects
- Ranging from machinery cooperatives, to testing of new concepts, and problem-solving around specific issues
- Peer-to-peer learning and demonstration

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Collective action – some existing examples

- 130+ LEADER projects focusing on climate action
  - L'arbre en Champ (FR & BE) – agroforestry audit and mobilisation
  - Cheviot Futures (UK) - wildfire management, tree planting
- French machinery cooperatives
- Scottish initiative Quality Meat Scotland (http://www.qmscotland.co.uk/events/paraban-reloaded)
- Harvesting and processing wetland biomass http://www.crops4energy.co.uk/decc-wetlands-biomass-bioenergy-competition/

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Collective action – examples of new topics

- Testing of regional schemes for N-efficiency and regional climate audit tools
- Development of regional strategies to increase resilience of forest stands to climate change
- Development of agro-forestry systems
- Farm resilience planning
- Production and certification of baking wheat without late 'quality fertilisation'
- Climate action networks (e.g. Farming for Better Climate)

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Concluding thoughts

- Actively engage land owners as problem-owners and problem-solvers
- Climate action can deliver multiple economic, adaptation and environmental objectives → landscape level management
- www.smartsoil.eu SmartSOIL Toolbox

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Thank you for your attention.

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We also gratefully acknowledge the inputs of external experts.

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Ricardo-AEA & IEEP on the 15th September

Institute for European Environmental Policy | RICARDO-AEA

Meta-review: Effective performance of tools for climate action policy

Mitigation potential from Agriculture and LULUCF

Hugh Martineau, J Webb (Ricardo-AEA)
Kaley Hart, Clunie Keenleyside (IEEP)

www.ricardo-aea.com

This presentation

- Assessment of suitability of potential mitigation actions for Agriculture and LULUCF
- Geographical relevance assessment
- Inventory analysis: Accounting for GHG mitigation within IPCCC guidelines
- Feasibility of using EU policy tools to improve uptake of mitigation actions
- Challenges and barriers to implementation
- Current and future policy support

Assessment of suitability: Mitigation actions for Agriculture and LULUCF

Screening potential actions

- Screening has been carried out by :
  - **Meta-review**: the findings of recent, or relatively recent, reviews of the potential for GHG abatement together with the results of recent studies to produce Marginal Abatement Cost Curves for the abatement of GHG emissions from agriculture
  - Expert judgement: understanding and detailed knowledge of proposed mitigation actions
  - March workshop outputs

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28 actions assessed

Land use
- Conversion of arable land to grassland
- Agro-forestry, short term forestry
- Improving grassland management
- Use of grassland to reduce forest fire risk
- Wetland conservation/ restoration
- Extend the perennial phase of crop rotations
- Woodland creation
- Woodland management

Crop production systems
- Reduced Tillage
- Zero Tillage
- Leaving Crop Residues on the soil surface
- Ceasing burning of vegetation & crop residues
- Biochar applied to soils
- Use cover/catch crops and reduce bare fallow

Energy
- Carbon auditing tools
- Anaerobic digestion
- Increased energy efficiency

Livestock Production
- Livestock disease management
- Use of sexed semen for breeding dairy replacements
- Breeding low methane emissions in ruminants
- Use of feed additives
- Optimise feed strategies

Manure, Fertiliser & Soil management
- Soil and nutrient management plans
- Delay applying mineral N to a crop that has already had slurry applied
- Use of urease inhibitors and next-generation nitrification inhibitors
- Improved nitrogen efficiency
- Biological N fixation in rotations and in grass mixes
- Maintain soil pH at suitable levels for crop/grass production

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Mitigation potential

Each of the potential mitigation actions has been assessed according to evidence available relating to each of the following:

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

A screening document was produced to asses the suitability of all mitigation actions reviewed

This is summarised in a matrix for a high level assessment of the suitability of actions

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Assessment Matrix - Example actions

Climate Action	GHG benefit	Accountability / Verifiability	Capital Costs	Ongoing Costs	Tech constraints	Benefits	Risks	Socio-economic barriers
Conversion of arable land to grassland to sequester carbon in the soil	++							
Wetland/peat land conservation/ restoration	+++							
Woodland creation	+++							
Reduced Tillage	+							
Use cover/catch crops and reduce bare fallow	+							
Livestock disease management	++							
Use of sexed semen for breeding dairy replacements	+							
Soil and nutrient management plans	+							
Use of urease inhibitors and nitrification inhibitors	+++							
Improved nitrogen efficiency	+							
Carbon auditing tools	+							
Anaerobic digestion	+							

- Multi-criteria approach to assess suitability of actions

Geographical relevance

Geographical Relevance

- The approach to determining if there is geographical relevance included an assessment of the factors that could affect the applicability of an action based on available.
- Criteria for assessment:

Parameter		Measure	Data Source
Land Use	Forestry/woodland	Area	(CAPRI)
	Permanent grassland	Area	(CAPRI)
	Permanent crops	Area	(CAPRI)
	Arable	Area	(CAPRI)
Soil	Texture	Average % clay/slit/sand content	(LUCAS)
	Soil organic carbon	% area of ranges of SOC	(OCTOP)
	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			

[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

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Geographical Relevance

Actions with geographical relevance	Primary parameters	Secondary parameters
Conversion of arable land to grassland to sequester carbon in the soil	Arable area	Soil Organic Carbon Soil Clay content
Wetland/peatland conservation & restoration	Soil organic carbon	
Woodland management	Woodland area	
Reduced tillage & No till	Arable area	Clay content Bio-climatic zone
Maintain soil pH at suitable levels for crop/grass production	Soil pH	
Livestock disease management	Livestock population	
Use of sexed semen for breeding dairy requirements	Dairy population	

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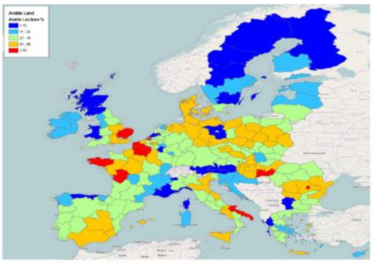
Geographical Relevance: example output

Arable to grassland: arable area



Arable area
- Blue = low (< 10% UAA)
- Red = high (> 60% UAA)

Relevance
Land must be arable to convert

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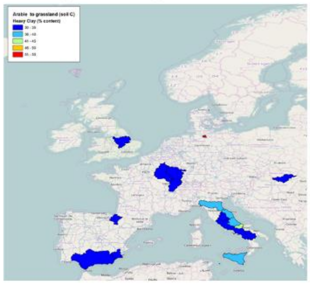
Geographical Relevance: example output

Arable to grassland: Heavy Soils



Clay content
- Map identifies areas with High proportions of land over 30% Clay content

Relevance
- Capacity to sequester carbon increases with clay content
- Cultivation challenges

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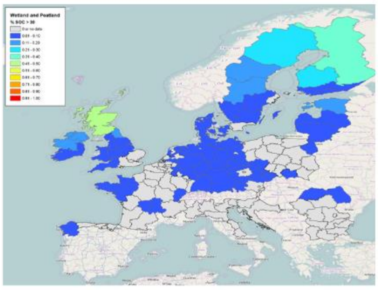
Geographical Relevance: example output

Wetland and peatland restoration and conservation



Proportion land over 30% SOC

Relevance
Restoration and conservation activities will focus in these areas

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Inventory challenges and limitations

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Overview of the inventory analysis

- Each mitigation action has been assessed to determine the impact on IPCC categories according to both 1996 and 2006 guidelines
- The National Inventory Reports of all Member States were reviewed to assess which MS record which categories as 'Key' and thus require either a tier 2 or 3 reporting requirement.

Example Categories	Member states Key Categories
Agricultural Soils	26
Enteric Fermentation	23
Cropland remaining cropland	21
Forestland Remaining Forestland	25
Grassland remaining Grassland	13
Wetland remaining wetland	5

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Overview of the inventory analysis

- The likely impact mitigation actions on inventories was reviewed in terms of how IPCC guidelines allow for each to be accounted for in inventories. They may:

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.
4. No impact direct impact on inventories as the mitigation action has an indirect impact

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Summary and questions

- The ability of inventories to detect mitigation is dependent on the level of sophistication of the inventory methodology for each category
- The ability to access robust activity data is key
- There is some variability in approaches across member states
- Points to consider
  - To what extent should a lack of ability to account limit the efforts to introduce potentially beneficial mitigation action?
  - What improvements need to be made to improve accounting for mitigation in Agriculture and LULUCF sectors?
    - Activity Data accuracy and collection
    - Improved, regionally specific emissions factors

Feasibility of using EU policy tools to improve uptake of mitigation actions

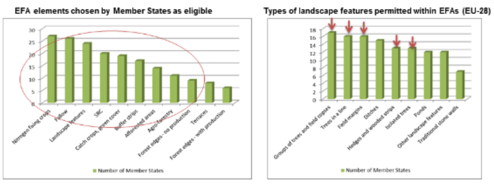
GAEC standards

Greening payment - EFA and environmentally sensitive permanent grassland

RDP measures

GAEC and Ecological Focus Areas (greening)

- 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
  - GAEC 7 - retention of landscape features
- Greening measures - EFA



Environmentally sensitive permanent grassland (greening)

	% ESPG in Natura 2000 (per MS or region)
BG	100%
CZ	100%
EL	100%
ES	100%
IT	100%
HU	100%
NL	100%
SK	100%
FI	100%
SE	100%
UK - E	100%
UK - W	100%
UK - NI	100%
HR	80%
CY	72%
DE	64%
FR	63%
BE - Fl	50%
LT	42%
PL	42%
UK - S	41%
BE - Wa	35%
SL	26%
LU	25%
DK	20%
AT	6%
LV	3%
IE	2%
PT	1%
EE	1%
Total %	74%
Total ha	7,491,763.65ha

Farmers are prohibited from converting or ploughing environmentally sensitive permanent grassland:

Inside Natura 2000 areas (obligatory)- ESPG can be:

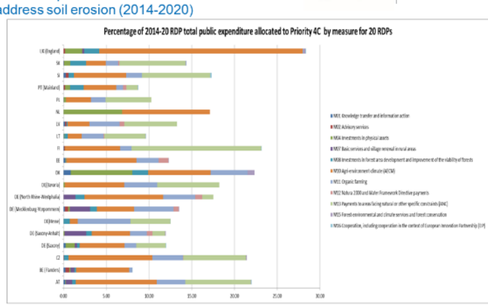
- soils with high % organic C (peat and wetlands)
- soils with high risk of erosion
- in a sensitive area designated under WFD

Outside Natura 2000 areas (optional):

- other environmentally valuable permanent grasslands, including those on C-rich soils

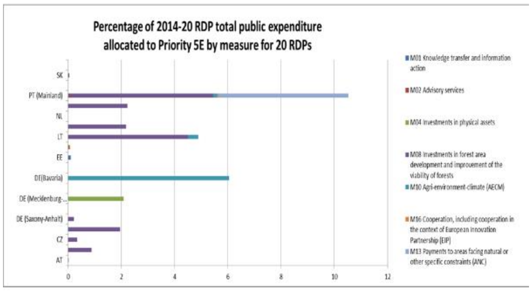
	Total area of designated sensitive grassland outside Natura 2000 (hectares
CZ	257,767.56
LV	5,739.00
LU	3,904.00
UK - W	53,718.00
Total	321,128.56

% RDP expenditure allocated to measures to address soil erosion (2014-2020)



NB: Calculated by dividing total expenditure allocated to Priority 4 by 3.

% 2014-2020 RDP expenditure allocated to: Priority 5b, 5d and 5e



Challenges and barriers to implementing climate mitigation actions

Distinguishing between freedom of choice and barriers to implementation

- Political will
- Policy inertia and risk averse behaviour by managing authorities
- Lack of synergy with other objectives and policies
- Limitations and availability of CAP policy tools
- Gaps in knowledge, methodologies and data
- Cross-sectoral and institutional factors
- Level of administrative effort/costs

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The role of current and future policy in improving and extending the use of climate mitigation actions on agriculture and forestry land

Where next – the role of current and future policy ?

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- Despite increasing implementation of climate mitigation actions by farmers, their use remains patchy both geographically and in terms of the types of measures adopted.
- The agriculture sector remains a significant emitter of non CO2 greenhouse gas emissions as well as CO2 emissions in some countries, particularly from cropland management
- There is a need to:
  - extend the use of those actions that are already technically feasible and cost-effective; and
  - encourage the implementation of actions that are less commonly used currently in the short, medium and longer term.
- Some of this will occur through the market, but where this is not the case, policy intervention may be required
- A range of opportunities:
  - Climate policy
  - Agriculture Policy, including the CAP

Climate policy: Inclusion of LULUCF within the EU GHG reduction target for 2030

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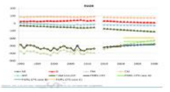
- Could increase the motivation of Member States to report and account for such emissions more rigorously.
- The degree to which this is the case in practice will depend on a range of factors:
  - how the LULUCF contribution to emission reduction targets will operate
  - the target set for a particular Member State
  - the current situation with regard to GHG emissions from the agriculture and LULUCF sectors (sources/sinks).
- But the ability to report emissions or removals from the sector accurately will become increasingly important
  - Where there are issues with reporting actions, this can be a barrier to promoting them to land managers or funding them via the CAP or other funding mechanisms.
  - This issue is likely only to grow in significance under the new climate framework post 2020.



Common Agricultural Policy (CAP)

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- The CAP 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
- One of the three core objectives for the CAP for the 2014-2020 period is to contribute to *'the sustainable use of natural resources and climate action'*.
- Not all climate mitigation actions are necessarily relevant for implementation within the CAP
- For those that are, there are a range of CAP measures that have the potential to be used to enhance emissions reductions from agriculture: cross-compliance GAEC standards/ Pillar 1 greening measures/ Pillar 2 rural development measures.
  - Not just for climate mitigation actions but as an important source of funding for the provision of advice, capacity building , demonstration activities – via Farm Advisory System and other national/regional/local initiatives




Determining which climate actions are relevant and where

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Decisions on the implementation of relevant climate mitigation actions via the CAP will need to consider:

- Need for public support
- Opportunity costs of implementation and risks of production displacement
- Cost-effectiveness in terms of climate benefits
- Scale of uptake and geographical targeting
- Integrated use of multiple policy measures in combination
- Promote actions that also contribute to the medium and long-term climate adaptation of agricultural and forestry systems, especially where these can also improve economic efficiency of businesses
- locations where the climate mitigation action maximises the other environmental benefits and has no adverse impact on the environment



Other beneficial aspects of the CAP

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- European Network for Rural Development
  - ENRD Contact Point and National Rural Networks - opportunities for sharing information and experience on climate mitigation actions within a country as well as between countries
  - EIP-AGRI - opportunities to bring researchers/scientists and practitioners together to discuss and share experiences on particular issues and come up with new and innovative ideas and approaches
- The CAP's Integrated Administration and Control System (IACS) has the potential to provide a wealth of information that could be used by Member State authorities for the purposes of 'agriculture' and 'LULUCF' reporting

In summary…

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- There are multiple opportunities to support climate goals in agriculture via policy, both through climate and agricultural policy
- There is more experience with the implementation and benefits of some climate mitigation actions than others:
  - The evidence base is variable - for some actions more evidence is needed to determine accurately their mitigation potential in different situations
  - More research and development is needed for some actions – role for Horizon 2020?
- But this is not a justification for inaction – important to take action now using the policy tools and evidence available and adapt as the body of evidence evolves over time - this is especially important for forestry because of the time lag in the production cycle

Appendix 4 – List of delegates

First Name	Surname	Company	Position In Company	Country
Szvetlana	Acs	European Commission - JRC	Policy Analyst	Belgium
Joana	Balsemao	Portuguese Permanent Representation to the EU	Attache	Belgium
Raimund	Becher	Bavarian State Ministry for Food, Agriculture and Forestry	Staff Member	Germany
Francesca	Bignami	FoodDrinkEurope	Manager	Belgium
Viorel	Blujdea	National Institute for Research and Development for Forest	Project Manager	Romania
Hannes	Boettcher	Oeko-Institut	Senior Researcher	Germany
Piotr	Borkowski	EUSTAFOR	Executive Director	Belgium
Nico	Bos	Ministry of Economic Affairs (The Netherlands) Nature & Biodiversity Department	Policy Advisor	Netherlands
Bjorn	Bostrom	Swedish Environmental Protection Agency	Policy Instruments for Climate and Air Unit	Sweden
Luc	Bouvarel	Private forest in France	Director	France
Matthias	Braun	Federal Ministry of Agriculture, Forestry, Environment and Water Management		Austria
Michael	Bucki	European Commission		Belgium
Grahame	Buss	Shell	Principal Scientist	UK
Susanna	Calsamigua	JRC		Belgium
Mads Helleberg Dorff	Christiansen	Danish Agriculture & Food Council	Chief Policy Advisor	Denmark
Peter	Coleman	DECC	Head of Land Use and Bioenergy Science	UK
Barbaros	Corekoglu	FEDIOL	Trade and Economic Affairs Manager	Belgium

Bernard	de Galembert	Confederation of European Paper Industries	Director Innovation & Bio economy	Belgium
Olivier	De Guibert	Ministry of Ecology, Sustainable Development and Energy	Head of Unit	France
Femke	de Jong	Carbon Market Watch	EU climate policy advisor	Belgium / Netherlands
Jos	Delbeke	European Commission	Director General DG CLIMA	Belgium
Pieter	de Pous	EEB	Policy Director	Belgium
Tiago	De Sousa	Ministère du Developpement durable et de Infrastructures	Attache	Luxembourg
Ariane	De Donivicis	European Commission - Secretary General		Belgium
Diana	Dibaru	Ministry of Agriculture and Rural development	Superior Counsellor	Romania
Mihail	Dumitru	European Commission	Dep. Director General , DG AGRI	Belgium
Dariusz	Dybka	Permanent Representation of the Republic of Poland to the EU	Environment Attache	Poland
James	Ede	Kellogg Company	Public Affairs Senior Manager	Belgium
Frida	Edstrom	Swedish Board of Agriculture	Analyst	Sweden
Christopher	Eichhorn	BMEL	Student	Germany
David	Ellison	Swedish University of Agricultural Sciences, SLU	External Consultant	Sweden
Sini	Erajaa	BirdLife Europe and European Environmental Bureau	EU Bioenergy Policy Officer	Belgium
Eamonn	Farrell	Irish Co-operative Organisation Society	Agri Food Policy Executive	Ireland
Eric	Fee	Federal Environment Agency	Science Policy Advisor	Germany
Nicolas	Ferenczi	AGPB	Head of Economics and International Affairs	France
Monika	Figaj	Ministry of Environment	Senior specialist	Poland

David	Fitzgerald	Dairygold	Environment Manager	Ireland
Stefan	Frank	IIASA	Researcher	Austria
Ana	Frelih Larsen	Ecologic Institute	Senior Fellow	Germany
Eric	Gall	IFOAM EU Group	Policy Manager	Belgium
Marta	Gaworska	The General Directorate of the State Forests	Head of International Cooperation	Poland
Ronan	Gleeson	Department of Agriculture, Food & Marine (IE)	Assistant Agricultural Inspector	Ireland
Mattias	Gotting	Federation of Swedish Farmers	EU Representative	Sweden
Tobias	Gras	Danish Agriculture and Food Council	Policy Advisor	Belgium
Garomo	Grassi	JRC		Belgium
Adam	Gubourge-Czewertynski	PL Perm Rep	Head of Environmental Policy Section	Poland
Andreas	Gumbert	European Commission, DG AGRI H4		Belgium
Andre	Guns	AWAC	Policy advisor	Belgium
Kaley	Hart	IEEP	Head of Agriculture	UK
Erika	Hasznos	European Commission DG CLIMA	Policy Officer	Belgium
Marta	Hernandez De La Cruz	Spanish office for climate change - Ministry of agriculture, food and environment	Technical Advisor	Spain
Koen	Holmstock	Department of agriculture and fisheries, Flanders	Policy Advisor	Belgium
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Juliette	Jacques	Starch Europe	Deputy Managing Director	Belgium
Ceris	Jones	National Farmers Union	Climate Change Adviser	UK
Matti	Kahra	Ministry of Agriculture and Forestry	Senior Specialist	Finland

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Simon	Kay	European Commission DG Climate Action		Belgium
Vaiva	Kazanavičiūtė	Department of National Forest Inventory -	Advisor	Lithuania
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Fintan	Kelly	The National Trust for Ireland	Agri-environment Office	Ireland
Kaser	Kivsoo	European Commission - DG Grow		Belgium
Mikkel Stein	Knudsen	Danish Agriculture & Food Council	Senior Advisor	Denmark
Kadi	Koiv	Ministry of the Environment	Counsellor	Estonia
Edit	Konya	European Commission - DG AGRI		Belgium
Stephanie	Kottl	LKO		Belgium
Evangelos	Koumentakos	Copa and Cogeca	Policy Advisor	Belgium
Morten	Ladefoged Petersen	Danish Energy Agency	Advisor	Denmark
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Ieva	Licite	Ministry of Agriculture	Senior Officer	Latvia
Claude	Lorea	CEMBUREAU, the European Cement Association	Deputy Chief Executive & Industrial Policy Director	Belgium
Mattias	Lundblad	Swedish University of Agricultural Sciences	Researcher	Sweden
Florence	Macherez	The Animal Task Force	Secretary General	Belgium
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Hanna	Mattila	Ministry of Agriculture and Forestry	Senior Officer	Finland
Silvia	Melegari	EOS	Secretary General	Belgium
Marco	Mensink	CEPI	Director General	Belgium
James	Mills	British Agricultural Bureau	Policy Adviser	UK
Gilles	Morellato	Environment and Climate at the Permanent Representation of France	Attache	France
Jerome	Mounsey	European Commission DG-CLIMA	Policy Officer	Belgium
Hannah	Mowat	Fern	Forest and Climate campaigner	Belgium
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Alessia	Musumarra	Confederazione italiana Agricoltori - Representative office to the EU	Policy Advisor	Belgium
Gert-Jan	Nabuurs	Alterra, Wageningen UR	Professor	Netherlands
Knut	Oistad	Mission of Norway to the EU	Counsellor Agriculture and Forestry	Belgium
Asger	Olesen	COWI A/S	European Market Manager	Denmark
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Claudia	Olazabal	European Commission - DG Env		Belgium
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Kamila	Paquel	IEEP	Senior Policy Analyst	Belgium
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Aljoscha	Requardt	Confederation of European Forest Owners (CEPF)	Secretary General	Belgium
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		Development of the Republic of Latvia		
Ignacio	Seoane	European Commission DG AGRI		Belgium
Katarzyna	Siekierska	Permanent Representation of Poland to the EU	Counsellor	Poland
Hélène	Simonin	European Dairy Association	Director Food, Environment & Health	Belgium
Yvon	Slingenberg	Cabinet of Commissioner Arias Canete, European Commission	Senior Advisor	Belgium
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Julia	Stark	Zentralverband Gartenbau e.V. (ZVG)	European Policy Officer	Germany
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Simon Apelblat	Thomsen	Ministry of Environment and Food of Denmark	Head of Section (advisor)	Denmark
Gerd	Thomsen	EUSTAFOR	Associate	Belgium
Steffen	Thoroe	EDA	Member	Denmark
Andreas	Thurner	Austrian Chamber of Agriculture	Head of Brussels Office	Austria
Juhani	Tirkkonen	Ministry of Employment and the Economy Finland	Chief Councillor	Finland
Ann-Kathrin	Trappenberg	IFOAM EU Group	Project coordinator	Belgium
Murielle	Trouillet	Ministry of agriculture, agrifood and forestry	Policy Officer	France
Gregory	Tsouris	European Commission - DG Clima	Policy Officer	Belgium
Paul	van Dam	Ministry of Infrastructure and the Environment	Policy Advisor	Netherlands
Tom	Van Ierland	European Commission - DG Clima		Belgium

Zalan	Varga	Ministry of Agriculture	Crop Production Specialist	Hungary
Johannes	Venneman	EFFAB		Belgium
Hegg	Vlla	Mission of Norway to the EU		Norway
Richard	Wakeford	Rural Strategy Consultant	Expert on Rural strategy	UK
Neil	Walker	Ibec	Head of Infrastructure, Energy and Environment	Ireland
J	Webb	Ricardo-AEA	Principal Consultant	UK
Peter	Wehrheim	European Commission (DG CLIMA)	Head of Unit	Belgium
Melanie	Yammine	IUCN	EU Policy Officer	Belgium
Diana elena	Zidaru	MADR	Counsellor	Romania
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Appendix 5 Delegate feedback form

Agriculture and LULUCF in 2030 EU Climate and Energy Framework

Feedback Form – 14 and 15 September 2015

Thank you for attending the event. Please take a few moments to complete this questionnaire as your feedback is very important to us and will assist in developing future activities. Please mark or tick the boxes (☑) that relate to your views and write in BLOCK CAPITALS.

Your Organisation

Your Name: .... Organisation: ....

Please specify your job title:
Policy Officer/Advisor ❑ Researcher ❑ Technical Expert ❑
Other please specify ....
Please specify your Member State ....

Which event did you attend?

Both Days ❑ Monday Only ❑ Tuesday Only ❑

Your Objectives

1. What were your primary objectives for attending the event?
   To further share your view on how to reduce GHG from agriculture and LULUCF ❑
   To understand how climate actions can be implemented through the framework ❑
   To hear about best practice in the agriculture and forestry sectors ❑
   To build networks and contacts with other policy makers ❑
   Other, please specify..
2. Did the event meet your objectives?
   Yes, fully ❑ Yes, partially ❑ No, please state why? ....

Workshop and Breakout Session

3. How did you rate the following:

14th September

	Excellent	Very good	Adequate	Poor
Introductory presentation	❑	❑	❑	❑
Panel discussion	❑	❑	❑	❑
GHG gases for agriculture, forestry & other land uses	❑	❑	❑	❑
Assessing objectives for agriculture, forestry & other land uses	❑	❑	❑	❑
Usefulness of the breakout session	❑	❑	❑	❑
Questions & answers with speakers	❑	❑	❑	❑
Opportunities for networking	❑	❑	❑	❑

15th September

	Excellent	Very good	Adequate	Poor
Introductory presentation	❑	❑	❑	❑
Success and best practice	❑	❑	❑	❑
Mitigation potential in Agriculture and LULUCF	❑	❑	❑	❑
Steps for the preparation of the Impact Assessment	❑	❑	❑	❑
Questions & answers with speakers	❑	❑	❑	❑
Opportunities for networking	❑	❑	❑	❑

4. What aspects of the event were the most valuable for you? And why?
   ....
   ....
5. How could we improve this event in the future? ....

……

Event Organisation

6. Please indicate your overall satisfaction for the following:

	Excellent	Very good	Adequate	Poor
Event administration and registration process	❑	❑	❑	❑
Event location	❑	❑	❑	❑
Event venue and facilities	❑	❑	❑	❑

COMMENTS FOR MONDAY 14TH SEPTEMBER ONLY

We welcome your comments whether as words of appreciation, comments on the content of presentations or constructive criticisms for future events. (Please write in BLOCK CAPITALS).

COMMENTS FOR TUESDAY 15TH SEPTEMBER ONLY

We welcome your comments whether as words of appreciation, comments on the content of presentations or constructive criticisms for future events. (Please write in BLOCK CAPITALS).

Thank you. Please leave your completed feedback form on the registration desk.

Annex 8: Consultation on addressing greenhouse gas emissions from agriculture and LULUCF in the context of the 2030 EU climate and energy framework

In October 2014, EU leaders agreed upon a greenhouse gas emissions reduction target of at least 40% by 2030 compared to 1990 together with other building blocks of the 2030 policy framework for climate and energy, as proposed by the European Commission in January 2014. The European Commission was invited to establish policy on how to include land use, land use change and forestry into the 2030 greenhouse gas mitigation framework.

Between March and June 2015, the European Commission launched a public consultation on how best to address the emissions from agriculture, forestry and other land use within the context of the 2030 EU climate and energy policy framework following the European Council's endorsement in October 2014. It sought input on the impact of existing policies on emission reductions from the LULUCF sector and three potential policy options for integrating LULUCF within the EU's 2030 climate and energy framework.

Review of the public consultation responses

There were a total of 135 responses to this public consultation. About 22% of the respondents are based in Belgium (this includes EU level associations), 10% in Ireland and 7.5% in Sweden with an overall contribution from 21 different Member States. The two largest respondent groups are NGOs (26%) - with a large majority of them being environmental and climate NGOs and a couple representing young people and nutrition - and sectoral associations (33%) representing mainly the agriculture and forestry sectors. Responses from Member States authorities account for 16%, with responses from 17 EU Member States, followed by individual businesses/farmers and academics/researchers groups (7.5% respectively), individual citizens and SMEs (roughly 5% and 4% respectively). Some 33% of respondents indicate they represent the agricultural sector, 24% the forestry sector and 43% other sectors.

General questions

The first part of the consultation sought information and stakeholders' views on various EU and international aspects relevant to LULUCF and that have an impact on the ways in which the LULUCF sector can be integrated into the 2030 climate and energy framework. The key issues and point raised are summarised below.

1.1 Enhancing the mitigation of the AFOLU section alongside its other multiple objectives – Questions 1 and 2

Of the multiple objectives of the agriculture, forestry and other land use sectors, Member State respondents indicate that ***food security*** will continue to be a key objective for the agricultural sector by 2030: it will remain key to maintain production levels and increase land productivity within the context of a growing population while at the same time reducing greenhouse gas emissions and protecting the EU's environmental resources, which continue to decline. The synergies between agriculture sectors (crop and livestock) will need to be optimised, to intensify production sustainably as a means of counterbalancing agriculture's limited potential for climate change mitigation[15]. NGOs further note that making EU agriculture and forestry more self-sufficient would avoid the continued import of emission intensive products (e.g. palm oil or soy) or raw material for bioenergy, while others highlight the role agriculture and forestry already play in achieving this to some extent.

The security of ***forest based biomass supplies*** is expected to gain in relative importance by 2030 within the context of an expanding bio-economy, particularly to substitute fossil fuels. Within the context of a growing forest sector, maintaining the ***long-term stability of carbon pools*** will be key according to NGOs, implying the combined enhancement of the sink capacity of existing forests (volume) and by afforesting unproductive areas (area).

The ***conservation and enhancement of soils and other natural resources*** will be an essential focus to avoid their depletion, e.g. improvement in soil carbon stocks to reduce all forms of soil erosion through improved cropland and forest management, conservation and restoration of peatlands and grassland, enhancing the provision of ecosystem services, including in aquaculture, to ensure protection *inter alia* of ***biodiversity and water quality***. Research and development is also highlighted as important to unlock the potential of GHG mitigation by the agricultural sector.

To optimise the production of renewable energy and raw materials, while fully exploiting the mitigation potential in these sectors, some respondents (mainly NGOs and some Member States) indicated that there should be ***a shift of policy focus*** from agricultural production ***to sustainable food and bioenergy consumption***. This should focus on measures that ensure high resource efficiency in the AFOLU sectors (e.g. implementing the cascading use principle, promoting energy efficiency), limiting food and other categories of waste, introducing robust sustainability criteria to ensure climate benefit, e.g. by capping bioenergy use to avoid unsustainable levels of supply, by enhancing carbon sinks, soil quality, biodiversity and other ecosystem services, including through use of the CAP for the agricultural sector. In terms of the AFOLU sector's contribution to renewable energy production, a few respondents highlighted that policy support should focus on bioenergy uses and feedstocks that can demonstrate effective emission savings (advanced biofuels), taking into account indirect land use change and carbon debt. In this context, they suggest that there should be full accounting for all land use activities to ensure that all emissions from biomass combustion are accounted for. Sustainable consumption should be encouraged through increased consumer awareness, e.g. to move away from high meat content diets.

With respect to ***forestry***, one forestry organisation highlighted the fact that 60% of the EU forests are managed via highly fragmented private forest ownership, and therefore that any policy on future land use and management will need to be able to mobilise action via private forest owners and most likely at the national level, given Member State competence for forestry policy. For forestry stakeholders, the full mitigation potential of the sector could be achieved with more investment in sustainable forest management and wood production and use (e.g. prioritising first material use rather than energy use, developing sustainable forest certification and timber marketing tools). They also highlight that the carbon sequestration benefits associated with the substitution of fossil-based materials and energy by forestry products both for materials and energy should be recognised (its full accounting would benefit the forestry sector).

[15] European Council Conclusions of October 2014

1.2 Ensuring a fair and equitable distribution of effort between Member States - Question 3

For some Member States and the agriculture and forestry sectors, a fair and equitable distribution of the effort required to fulfil the EU's commitment would imply a shared effort proportionate to the Member States' mitigation potential in the AFOLU sector.

It is noted that each Member State has a different emission profile, mitigation potential and climate adaptation needs so it could be considered unfair to distribute the effort sharing between Member States without taking these variations into account. Member States also have the best knowledge of the strategies and tools most appropriate to the national AFOLU sector. However, according to the forestry sector, any distribution of effort should be carefully framed and there should be no trade-offs between Member States (to avoid in particular the offsetting of emissions by forest rich countries). For these respondents, the accounting rules in Decision 529/2013 should be used as the basis for more comprehensive accounting of LULUCF activities.

Some NGOs however highlight the fact that many sectors also show considerable emission variability between Member States and between years, therefore these respondents see limited rationale for accommodating the AFOLU sector within the ESD. Where there are technical issues, such as the difficulty of base year age class structure in forest management, technical solutions exist, for example using base periods rather than years.

Many of points raised in response to this question are reflected in the policy option section below.

1.3 Promising measures and technologies for reducing GHG emissions and barriers to their adoption – Questions 4 and 5

The ***most promising and cost effective GHG reduction policy measures/actions*** are generally considered by respondents to be the ones that meet multiple objectives. A number of examples were provided, for example improved livestock feeding techniques, or simply the promotion of more extensive farming (grazing), to help reduce methane and nitrous oxide emissions while improving air quality and reducing the EU protein deficit.

In terms of promising and cost effective ***policies,*** a number of different policy measures are identified as having potential for improvement. The set-up of a full accounting system for all LULUCF emissions/removals in the new framework would be key in this regard for some respondents, as would be an increased policy focus on different aspects of sustainable intensification, including sustainable forest management. A reform of bioenergy policies to take into account the true carbon balance of bioenergy, including changes in carbon stocks, ILUC and carbon debt would also have significant emission reduction potential according to some respondents. In a similar vein, the inclusion of so-called green fertilisers in the ongoing revision of the EU Fertilisers Regulation (EC) No 2003/2003 is also seen as a promising and cost effective policy change.

Policies focusing on more sustainable agricultural production and food consumption would naturally help promote lower and more efficient inputs, waste reduction, but could also constrain the intensive livestock sectors. Measures employed could include direct policy incentives or penalties, or be more indirect via promoting diet shifts. Measuring the carbon footprint of major food commodities to set benchmarks could provide useful performance information to farmers.

Several respondents noted that existing policies already achieve some GHG emission reductions for certain pollutants, such as the Nitrates Directive and the National Emission

Ceiling Directive, by encouraging better manure and nitrogen management as well as use of cover crops.

In terms of actual GHG emissions reduction ***actions*** that are promising and cost effective, respondents express a need for more research and development in a number of sectors: advanced biofuels; improved understanding of Monitoring, Reporting and Verification (MRV) systems for carbon stock changes in agricultural soils; building technologies using wood products and composites; genetics, for example to improve forest genetic resources to enhance climatic and pest tolerance or in agriculture for breed improvement; other animal husbandry actions, such as feeding and nutrient management techniques to reduce emissions intensity.

As regards existing techniques, using waste and residues rather than crops or primary wood for bioenergy production is highlighted as one means of saving emissions. More effective fertiliser use could also be achieved and would reduce emissions of N2O and CH4. In the forestry/wood sectors, greater use of shorter rotation periods, using more productive tree species, could be prioritised to take advantage of the most productive phase of the tree's life cycle.

Agricultural respondents highlighted that EU farmers already focus on climate change mitigation and on ensuring an efficient use of farm resources and energy – especially as this also enhances their overall economic performance, e.g. measures related to manure management.

However, numerous ***obstacles*** are reported by respondents that prevent greater implementation of climate mitigation policy measures and actions.

First, all sectors highlight the high pressure they face from alternative land uses. In the agricultural sector, farmers face a very competitive and efficient world market while in the forestry sector there is a slow pace of change and long timeframe from investment to return. The AFOLU sector in general is characterised by a time delay in implementing policy measures and actions to limit climate mitigation efforts where action needs to be taken by land managers. The fragmentation and the diversity of the agriculture and forestry sectors often hinder the smooth implementation of measures. Although financial incentives or information about GHG reduction measures may exist, decisions regarding management and harvest are driven by a wide variety of factors which are outside the reach of policies (e.g. land managers' personal situation, lack of knowledge transfer and farmers' education).

Some respondents however point out that there are limited direct incentives for emission reductions, given that the benefits in terms of saved emission units are often limited (and delayed) compared to the efforts required to put the actions in place. Furthermore, the indirect incentives through the generation of financial co-benefits are also very limited. The additional cost of measures is also not likely to be the same in all EU Member States which could result in competitive disadvantage for those willing to implement measures.

With respect to implementation, the high variability of situations in the EU AFOLU sector lead to a large degree of uncertainty as to what can be achieved (compared with the ESD sectors) as well as how the policy measures/actions implemented and their outcomes can be monitored and quantified, e.g. complex rules apply to forestry under the Kyoto Protocol. Furthermore, the outcomes also depend on external drivers (time in the year, weather conditions) which reduce certainty and therefore incentive. There could even be potential counter effects of mitigation measures, typically between anaerobic and aerobic processes (N2O versus CH4 emissions).

Other respondents indicate that support to bioenergy as part of the Renewable Energy Directive has undermined the ability of the bioenergy producing sectors to reduce emissions. In the future, the policy incentives need to be implemented in the sector they target to avoid a situation where energy policies drive an increase in bioenergy use and production in the AFOLU sector.

1.4 Accounting, target and flexibility rules – Question 6

For some Member State respondents, the rules laid down in Decision 529/2013 provide clear incentives and policy signals for investment in mitigation. The Decision should be the starting point for the new framework, with all LULUCF activities being accounted for.

With the current net-net accounting approach for ***cropland and grassland management***, emissions are often more related to the land-use change than to actual carbon stock evolution on the land parcel. Moreover, the areas of cropland and grassland in 1990 largely determine the outcome in terms of emissions and removals in the commitment period, rather than the soil carbon content. Some respondents suggest that this should be reviewed to eliminate any potential adverse effects. A reference period based on a five-year average and a more recent period such as 2005 rather than a single reference year could be used, while taking into account relevant past mitigation efforts. Furthermore, the current accounting rules could include special provisions in the case of extreme weather events for cropland and grassland management.

In ***forest management,*** the sector argue that the artificial and complicated accounting rules resulting from Kyoto negotiations should be replaced by a simpler and more transparent approach reflecting biophysical conditions so that a factual forest sink cannot become a source due to accounting rules.

Other respondents consider that Member States should account for all anthropogenic emissions and removals from a historical base year or period – and not from projected reference levels as is currently the case in forest management. Accounting against a commitment period and not annually received wide support from respondents. For others however, the forest management reference levels are considered a promising approach, although this will need to be confirmed in upcoming years, when the projected levels can be compared with actual emission/removals. Forest management reference levels would need to be updated for the period 2021 to 2030.

With accounting rules becoming mandatory for cropland and grazing land management from 2020 in the EU, some NGO respondents would like accounting rules in the other non-forest LULUCF activities also to become mandatory after 2020, especially for wetland drainage and rewetting (currently voluntary).

For some respondents, LULUCF and agriculture should be treated coherently to reflect key linkages between the sectors and to improve cost effectiveness. Monitoring and reporting of LULUCF and agriculture should be enhanced by introducing benchmarks for performance and harmonised rules to improve comparability and verification. For example, criteria could be put in place to ensure that the carbon sequestration action does not undermine other objectives such as biodiversity. Environmental criteria could act as thresholds i.e. if the environmental criteria are not met, a credit cannot count. Coordinated planning, reporting and presentation of information between the LULUCF Accounting Decision (accommodating variability and long lead times for LULUCF emissions/removals) and the Greenhouse gas Monitoring Mechanism Regulation (MMR) could promote long term policy coherency between linked sectors (e.g. agriculture and waste).

Although responses diverged on ***target setting*** (see below), for some respondents LULUCF should continue to be dealt with separately, with a separate target set for this sector to encourage Member States to incentivise action.

Another possible improvement could be to switch to a ***land-based approach*** in line with the UNCCC rather than an activity-based approach as under the Kyoto Protocol. This could ensure a more comprehensive coverage of emissions and removals and simplify both the reporting and the accounting and increase comparability of accounting data with Parties not included in the Kyoto Protocol. In all cases, the evolution of the international agreements and accounting options should be taken into account in any changes that are proposed to the existing rules.

Policy options: preferences, advantages and disadvantages of the options

The consultation sought views on which of the three policy options outlined in the document was considered to be the preferred approach for integrating the LULUCF sector within the climate and energy framework and reasoning for the choices made.

Respondents expressed their views and concerns in different ways. Some respondents chose a specific Option but specified the conditions under which they would consider the Option truly acceptable. Others respondents chose to opt for a 'combination of options' as a means of specifying the conditions or mix of approaches that would need to be in place for a particular policy Option to be acceptable. In fact, for all options, the specific rules, as yet not specified, on flexibility, accounting and target setting will influence any advantages and disadvantages they may have. Depending on the decision that will ultimately be made on these rules, all the options could result in very similar outcomes in practice. This explains the diverging understanding as to what the implications of the options might be by different respondents. The assumptions made by respondents on these three cross cutting issues are therefore critical to understanding what approach they prefer. As a consequence, simply identifying how many stakeholders favoured which option can be misleading. It should be noted also that the review of the responses to this public consultation does not provide a statistically representative picture of the EU, with some Member States and sectoral organisations being over- or under-represented according to interest.

The commentary presented in this document has focused on elucidating the pros and cons of each option as expressed by respondents, drawing on responses to all relevant questions of the consultation.

1.5 Option 1 - the LULUCF pillar: Maintain non-CO2 agriculture sector emissions in a potential future Effort Sharing Decision, and further develop a LULUCF sector policy approach separately.

Overall 34 per cent of respondents were in favour of keeping LULUCF as a separate pillar within the climate and energy framework, which makes Option 1 the preferred option for those respondents that provided a reply to this question. Option 1 received strong support from the majority of the environmental and climate NGOs and from the forestry sector and it is also the preferred option of some agriculture organisations and four Member States (out of 17 responding Member States). It was also supported to some extent by other interest groups including one research institution and one SME.

One of the main **advantages** put forward by these respondents is the fact that Option 1 would ensure ***continuity*** with the approach followed so far for reporting and accounting for LULUCF emissions and removals and is therefore considered by some respondents to be the option that is ***most easily operational*** in the short term. By maintaining non-CO2 agriculture emissions in a potential ESD, Option 1 would allow the LULUCF sector to be addressed independently, taking into account the ***specificities of the sector***, and thereby enabling the development of sector-specific policies, targets and accounting rules.

With most of its activities taking place in the natural environment, climate measures in the LULUCF sector have different mitigation potentials in different locations, depending on a combination of different factors, including crop type, soil type and/or climate zone. Emissions/removals are difficult to predict accurately year on year and some emissions will be inevitable. The LULUCF sector is therefore characterised by a high level of uncertainty due to the inherent inter-annual natural variability of emissions/removals, long-time cycles compared to ESD sectors (hence delayed effect of some mitigation measures) and the issue of non-permanence of carbon stocks. Moreover, issues with the reliability of measurement methods in the LULUCF sector, and forestry in particular, bring about additional uncertainty due to the different categories of land use and different geographies/climates. For this reason, some respondents indicate that the annual accounting cycle that applies to the ESD sectors would not be appropriate for the LULUCF sector as it could lead to errors in the annual accounts. However, Option 1 could respond to inter-annual variability, for instance by introducing ‘banking and borrowing’ or ‘averaging’ provisions for LULUCF emissions.

One respondent considers that addressing LULUCF separately could create technological and financial ***incentives*** to boost the sector’s varied mitigation potential at an improved cost efficiency ratio, provided a binding target is set for the LULUCF pillar (see also ‘Information gaps’).

A large majority of respondents, including NGOs, one agricultural organisation and one Member State, consider that Option 1 would contribute to ***maintaining environmental integrity***; in other words, that the current carbon sink represented by the LULUCF sector (by forests in particular) is not used to offset a reduced effort in other ESD sectors, thereby preserving the intended objective of the climate and energy framework. Most responses under Option 1 assumed that the LULUCF Pillar would have its ***own emission target*** and that ***flexibility*** with ESD sectors would not be allowed, largely due to the continuing uncertainties and variability in LULUCF accounting. For others however, rules to allow flexibility between the LULUCF pillar and the ESD sectors could be envisaged, although precisely how this would work is not specified (see ‘Information gaps’). If a high degree of flexibility between a LULUCF Pillar and other ESD sectors were to be allowed, one respondent reflected that this would result in Option 1 being very similar to Option 3 – the difference being that a LULUCF specific target seems more likely under Option 1 and this would allow for the recognition of MS specific LULUCF situations.

With regards to ***target setting***, most respondents assumed that LULUCF targets/efforts would be defined at the level of each Member State, with some Member States highlighting the importance of giving appropriate consideration of the ***Member States’ individual mitigation potential in the LULUCF sector*** when defining their respective targets.

Respondents from all interest groups also indicate a number of **disadvantages** of Option 1. Option 1 would carry on with a divided approach to agriculture emissions/removals, with the exclusion of non-CO_2 agricultural emissions from LULUCF. For some respondents, Option 1 would thus have ***limited policy coherence*** considering that non CO2 agricultural emissions and LULUCF sector emissions are to a large extent influenced by the same policies (see also other advantages of Option 2).

A number of respondents from different interest groups (sector organisations, academics, Member States) assumed that there would be no ***flexibility*** between the LULUCF Pillar and the other ESD sectors. If this were the case, they would view this as potentially requiring land managers to take more actions in the LULUCF sector compared to a situation where the target can flexibly be met with efforts in various sectors. This would be likely to entail the implementation of actions with higher marginal abatement costs in the LULUCF sector, in case GHG emission reductions provided by the lowest cost actions are insufficient to fulfil the target. Furthermore, efforts made in the ESD sectors having an impact on LULUCF would not be credited in the LULUCF pillar under this assumption.

Beyond the potential implications for marginal abatement costs, some NGOs fear that Option 1 ***would not provide*** stakeholders involved in the LULUCF sector with ***enough incentive for action*** on LULUCF if it were to remain a separate area, as is currently the case. This fear is based on an assumption that no target would be set for the LULUCF pillar, which may not be the case in practice.

1.6 Option 2 — Land use sector pillar: Merging the LULUCF and agriculture sector non-CO2 emissions into one new and independent pillar of the EU's climate policy.

Overall 19 percent of respondents were in favour of merging the LULUCF and non-CO2 agricultural sector emissions into a separate pillar - the agriculture, forestry and other land uses (AFOLU) pillar. This option is generally supported by stakeholders of the agricultural sector –albeit not systematically. It is also supported by Eurostat, two Member States (provided certain conditions apply) and by a couple of individual businesses and research institutes respectively. A number of other Member States also note considerable advantages with this approach, although they do not come down definitively in its favour.

The **advantages** put forward by respondents in favour of Option 2 include the fact that it would provide an ***integrated and holistic approach for the AFOLU sector***. For those favouring this approach, bringing together non-CO2 agricultural emissions and LULUCF is considered to have greater potential than Option 1 to promote the development of a coherent mitigation policy and set of actions adapted to the complexity and specific issues of the AFOLU sector. This could support the development of a long term policy vision for the AFOLU sector as a whole. For agricultural activities, the merger of all emissions/removals into one pillar could provide ***better alignment with existing agricultural policies, e.g. the CAP*** and would facilitate the use of the CAP as a means of promoting for climate mitigation action in the sector.

This in turn could improve the visibility of the issue and encourage farmers/foresters to maximise carbon stocks on their land. One industry representative and one Member State also considered that the joint treatment of all land-based activities could be a first step towards establishing a holistic approach to model and address iLUC issues relating to biomass production for bioenergy, allowing trade-offs in emissions as part of a full life cycle assessment. Moreover, Eurostat considers that once implemented Option 2 would be the most straightforward option in terms of ***comparability of data between Member States***.

According to farmers' organisations and Member States with limited AFOLU mitigation potential[16], Option 2 would enable the implementation of ***cost-effective solutions,*** whereby shared accounting with AFOLU carbon sinks (e.g. agricultural soils and forests) providing some ***flexibility to offset CH4 and NO2 emissions from agriculture***. Other respondents, notably environmental NGOs, however argue against this flexibility – the specific nature of which remains to be defined (see 'Information gaps').

Option 2 could however also have several **disadvantages.** Of the ***technical challenges*** raised by a range of respondents from different backgrounds, Option 2 would require a ***substantial transformation of the current EU climate policy***. A number of Member States, NGOs and industry respondents anticipate that ***target setting*** for the AFOLU sector, especially establishing an *ex-ante* target, would raise considerable difficulties given the complexity of merging two different emissions sources. This could also result in major ***accounting uncertainty***, with one NGO indicating that ***technical corrections*** to methodologies used to calculate LULUCF (forestry) emissions in the past have led to changes in the results of up to 80%[17]. This is considered to undermine considerably any advantages of Option 2. For other respondents, additional difficulties would result from the ***distribution of the effort/target between Member States*** and question what criteria would be used to determine this.

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[16] Countries experiencing limited mitigation potential in the AFOLU sector may do so for a number of reasons, e.g. where there are significant pressures on land or where very efficient mitigation measures have already achieved in the agriculture/LULUCF sector.
[17] Öko-Institut, June 2015. *Impacts on the EU 2030 climate target of including LULUCF in the climate and energy policy framework*. Report prepared for Fern and IFOAM.

As with Option 1, some Member States, researchers, agricultural and industry sector respondents note that the creation of a sector-specific target ***reduces in principle the flexibility between sectors and therefore the potential cost effectiveness*** of mitigation measures and actions (higher abatement costs).

As a counterpart to the advantages of increased flexibility of a single AFOLU pillar highlighted by the farming industry and some Member States above, forestry respondents, NGOs and some Member States see the potential for forest carbon sinks to be used to ***offset emissions*** from other ESD sectors (depending on the rules on flexibility between pillars), or ***within the AFOLU sector itself*** as a significant risk to the sector, potentially constraining its growth. Another wider forestry-related issue raised is that any options would require a ***transfer of the current Member State competence for forestry to the EU level***, a shift of competence that would raise subsidiarity issues (see also 1.8).

Finally other issues raised include the fact that the withdrawal of agricultural emissions from the ESD could be criticised as a step backwards in the EU's commitment vis-à-vis the international community and that by removing non-CO_2 agricultural emissions from the ESD, close links between the agriculture and waste sectors under the ESD could be lost.

1.7 Option 3 — Effort Sharing: Include the LULUCF sector in a potential future Effort Sharing Decision.

Overall 10 percent of respondents were in favour of integrating the LULUCF sector within a future ESD. Of the 17 responding Member States, three Member States support Option 3. An additional Member State would also support Option 3 if LULUCF accounting rules were defined in a way that provides clear incentives for sustainable policies in the long-term. No clear consensus emerges from the other interest groups in support of Option 3.

With respect to its **advantages**, Option 3 is considered by a wide array of respondents to constitute the ***most coherent approach to*** GHG reduction targets since it would integrate all relevant sectors under one Effort Sharing Decision (ESD). In addition, Option 3 is the only option that would consider the agricultural and wood supply chain emissions together, by combining all ***LULUCF activities with their related ESD activities*** under the same pillar[18]: the forest management sector (LULUCF) and its downstream wood supply chain (ESD), and in the agricultural sector, agricultural soil management (LULUCF) with biofuels and mechanisation activities (ESD) as well as with non-CO2 agricultural emissions (as in Option 2). For some respondents, this should encourage a more integrated and systemic approach to climate mitigation in these supply chains and ***incentivise action and investment*** in mitigation within the LULUCF sector, as it currently does for other sectors.

Some Member States and researchers suggest that Option 3 could constitute a good approach to address the issue of ***accounting for biomass use for energy***. Under the current IPCC rules, CO2 emissions from burning of biomass are not accounted in the ETS sectors but are to be accounted for in the LULUCF sector by a decrease in carbon stocks – to avoid double counting. For a majority of respondents, this is seen as leading to major gaps in biomass emission accounting. Option 3 may thus create the necessary linkages for a more coherent accounting of biomass use emissions, i.e. ensuring that an increase in biomass use for energy is correctly reflected by a decrease in carbon stocks and therefore that all emissions are accounted for. It should, however, be noted that these linkages would need to be accompanied by a review of existing policy infrastructure to ensure that carbon stock impact is properly

[18] While Option 2 would combine the non-CO2 and CO2 emissions/removals from agricultural land, Option 3 is the only option that would also allow forestry emissions throughout the wood supply chain to be reported and accounted for under the same framework.

translated across incentives and other tools that promote investment and decision making by end users.

Option 3 is considered by many as ***providing the highest flexibility to achieve the ESD target.*** Member States with limited agriculture or LULUCF mitigation potential[19] insist that target setting should be set in accordance with local circumstances. In general, these Member States consider that Options 1 and 2 would place them at a competitive disadvantage vis-a-vis other Member States but that, on the other hand, the combined treatment of ESD and LULUCF would offer them the flexibility they need to achieve their overall target in the ***most cost-effective manner***, i.e. most likely by increasing efforts in non-LULUCF sectors while benefitting from any sinks brought by LULUCF.

For most respondents, one of the main **disadvantages** associated with Option 3 is the risk that the carbon sink represented by the ***LULUCF sector*** would be used to systematically ***offset emissions in other ESD sectors*** thereby undermining the general objective of the climate and energy framework. According to one NGO, this would occur particularly in sectors with a mid to high marginal abatement costs[20] which is equivalent to reducing emission effort by about 185 MtCO2e. Another study, commissioned by environmental NGOs[21] show that when these sinks are taken into account, the overall target that would need to be met by emission reductions would effectively be reduced to approximately 35%. Another similar risk identified would be that no effort is made on LULUCF, rather emissions from this sector are offset by other ESD sectors with higher mitigation potential (as above). NGOs further argue that it would not be fair if Member States were allowed to pick and choose activities that are accounted for. In Member States where LULUCF is a sink, Option 3 could also increase the number of Annual Emissions Allocations available for exchange potentially undermining their marketability.

More generally, respondents from the forestry sector unanimously consider that Option 3 would put ***new pressure on forests*** to play a carbon sequestration role in the EU. As forests sinks rely on the maintenance of passive timber assets, this would constrain the development of the forestry sector in a context of forecast expansion of EU wood production for biomass and wood material in the coming years.

For some respondents, Option 3 would be very detrimental if the LULUCF target under Option 3 was calculated according to the ***current ESD criteria*** (GDP per capita) as this would not reflect the real potential contribution of LULUCF at Member State level. In practice, it seems likely that given the large differences in LULUCF potentials among EU Member States, Option 3 would entail ***target setting at Member State level*** using LULUCF-specific criteria, with their integration within the overall ESD target in a second phase. Therefore while Option 3 might seem in principle to be much simpler in terms of ***target setting,*** it could in practice result in a difficult exercise.

Some also highlight that Option 3 could create a ***greater level of uncertainty in view of the variability in emissions observed in the LULUCF sector, the lack of defined accounting rules*** for the LULUCF sector for the period post-2020 and in the absence of a robust and stable accounting system for forestry in particular. Respondents from all groups (researchers, Member States, NGOs, sectoral organisations) further stress the ***substantial methodological and accounting issues*** posed by Option 3, especially for the discrepancy between the ESD annual reporting and the LULUCF cycles (with the collection of carbon data for forest

[19] Countries experiencing limited mitigation potential in the AFOLU sector may do so for a number of reasons, e.g. where there are significant pressures on land or where very efficient mitigation measures have already achieved in the agriculture/LULUCF sector.
[20] Estimated as >25 EUR/tCO2e
[21] Öko-Institut, June 2015. *Impacts on the EU 2030 climate target of including LULUCF in the climate and energy policy framework*. Report prepared for Fern and IFOAM.

inventories taking between 5 and 10 years to complete)[22]. For other respondents, the specificities of the LULUCF are such that they would imply ***specific accounting rules*** for the LULUCF sector, which would be almost equivalent to Option 1. A couple of NGOs also argue that this approach, like Options 1 and 2, would not take account of bioenergy emissions from indirect land use changes (iLUC) and imported biomass.

Given that the LULUCF sector is a net sink at present in the EU[23], the inclusion of the LULUCF sector in the ESD could have an impact on the ***environmental integrity*** of the EU's climate framework 40% target, depending on whether it is associated with an increased level of ambition or not. If not, this could potentially be criticised at the international level.

1.8 A combination of options and common issues arising

A number of respondents have proposed a combination of the different options identified as their preferred approach. For example, two NGOs and two out of the 17 responding Member States indicate a preference for a combination of Options 1 and 2. One local authority also favours a combination of Options 1 and 3. Two researchers and a civil society group also selected different combinations of options under this choice.

Taking into account the advantages and disadvantages of each option as outlined above, respondents in favour of a combination of **Options 1 and 2** stress ***the need to address LULUCF independently***. While Option 2 is appealing in that it would embrace different aspects of agricultural land management, respondents recognise the ***technical challenges*** of such an approach. As a result, a combination of Options 1 and 2 seem to offer an interesting compromise – although the details of how this approach would be structured or operate are not clearly defined.

The combination of Option 1 with **Option 3** is deemed to combine the advantages of Option 1 –mitigation policy measures and actions and specific accounting rules adapted to LULUCF,– with those of Option 3, especially the ***flexibility and the cost-effective mitigation solutions*** expected to be brought about by the incorporation of LULUCF in the ESD target.

A few environmental and climate NGOs believe that ***an issue common to all options is the inclusion of forest management*** which raises many difficulties and risks bringing incoherence into the policy framework. It is argued that while there are commonalities across LULUCF, there are also many differences. Furthermore the EU has competence over agriculture policy but not over forest policy. Another key problem posed by the integration of forest management is considered to be the unreliability of the current accounting system which does not reflect the real emissions and removals in the forestry sector – this is argued not to be the case of the current agriculture system. In response to this, a number of environmental NGOs believe that ***forest management should be separated*** from other LULUCF sectors and dealt with independently, while ***non-CO2 emissions from agriculture and the remaining LULUCF activities*** (cropland management, grazing land management and wetland drainage and rewetting) should be integrated into the ESD as foreseen in Option 3.

1.9 No preference/no response

A signification proportion of respondents, notably the Member States (8 out of 17 responding Member States) but also respondents from the agricultural sector, individual businesses and citizens and researchers do not take a position on the preferred option to address GHG emissions from agriculture and LULUCF for the 2030 EU climate and energy framework. The main reason provided by respondents is the current lack of more detailed information regarding accounting rules, target setting and flexibility which, for some respondents, provides an insufficient basis for assessing and making a judgement on the different options. Some indicate

[22] It should be highlighted that all sectors in the GHG inventory are subject to some recalculations to adapt to the annual reporting periods of ESD, however, for the LULUCF sector, this exercise is considered to be particularly cumbersome.
[23] However, it is not a net sink for all MS individually and projections show this sink is likely to decline over time.

that the accounting rules and the selection of Options should have been examined jointly in this consultation. For other respondents, accounting rules for LULUCF in the post-2020 period should be agreed first, before the 2030 framework can be discussed. The fact that the forthcoming international discussions on LULUCF will also have a bearing on the decision taken in the EU's 2030 climate and energy framework is also highlighted.

1.10 Information gaps

All responses show some inconsistencies as to what respondents assume under each option for the three crosscutting issues that are yet to be defined: accounting rules, target setting and flexibility to offset emissions between sectors. Recurring information gaps highlighted are identified below for the following crosscutting issues.

Accounting rules: Respondents are unclear on how the specific characteristics of LULUCF would be taken into account, notably the inter-annual variability leading to e.g. time cycle issue and a need for specific (non-annual) compliance rules, the issues with the robustness of the data under current measurement and accounting systems and the issue of having long lead time for forest inventories and effects of mitigation measures in the LULUCF sector more generally. Other accounting rules yet to be defined and which have prevented respondents from taking a position include: the base year for net-net accounting of agricultural activities; and the reference level for forest management (if this approach is to remain in place). On the latter point, some NGOs argue that the accounting of all land categories should be based on an historic baseline rather than a projected reference level, as is currently the case for forestry. Furthermore, they highlight that rules to address the issue of the non-permanence of carbon sequestration and ways to ensuring that biomass use under the ESD is accounted for comprehensively in LULUCF should also be clarified.

Target setting: for the different options, respondents are unclear as to whether or not a separate target would be set for the newly created pillar (including for Option 3), whether this target would be defined at EU or Member State level – expressing different views about this - and on which criteria the potential Member State distribution of the target would be determined. Respondents that did take a position on a preferred option often made more or less explicit assumptions regarding target setting.

Flexibility: many respondents indicated they could not take a decision due to lack of information on the nature of any flexibility that would be allowed between sectors and within the LULUCF sector itself, e.g. whether and to what extent credit or debit exchange would be allowed. It is also not clear whether there would be any limits to the LULUCF contribution (discount or caps) to the mitigation effort required in other sectors. More generally on this issue, respondents question how LULUCF would interact in practice with the EU-level 40% climate target.

Annex: Policy options examined

Option 1, the LULUCF pillar, would continue the status quo, i.e. separate treatment of LULUCF. Accounting rules, targets and appropriate measures could be further developed. Flexibilities with regard to other sectors could be considered. The major disadvantage of this option is that agricultural and LULUCF emissions (including those of agricultural soils) would continue to be addressed by different policy tools, reducing policy coherence and rendering the design of incentives for action more complex.

Option 2 ("Land use sector pillar"): Under this option a separate pillar in the EU's climate policy, the Land Use Sector, would be created by merging LULUCF and non-CO2 emissions from the agriculture sector into one new and independent pillar of the EU's climate policy. Such a sector would include all emissions and removals related to agriculture and LULUCF. It could lack the advantage of flexibility between sectors within the overall Effort Sharing Decision, but give an opportunity for a policy approach that reflects the sector's specific particularities (e.g. permanence, long time-cycles, high natural interannual variability).

Option 3 ("Effort sharing") would increase the number of sectors in the ESD and thus increase flexibility for Member States to achieve a given overall target. It would also enable an integrated approach. However, it would increase complexity and raise methodological issues, including concerns related to environmental integrity and technical compliance issues, which would have to be specifically addressed (e.g. potentially large annual fluctuations in removals and emissions).

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