Sectoral assessment for agriculture, forestry and other land use

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Contents

1 Executive Summary

This report addresses the issues and challenges associated with policy mechanisms to deliver climate mitigation in the agriculture, forestry and other land use sectors (AFOLU). It looks at experience so far in driving mitigation, both in the EU and in other economies; and it provides a brief overview of possible mechanisms. It identifies the practicability and other issues associated with decarbonisation policies for the sector, including how they might work effectively alongside policies for the wider economy; and highlights the areas where supporting policies are needed to address gaps in decarbonisation activity in the sector. In particular, it places decarbonisation incentives in the context of other public goods and benefits associated with the sector, particularly environment ones. While it does not provide a detailed quantitative assessment of mitigation potential from particular AFOLU activities, it refers to earlier work by others, particularly the Committee on Climate Change, to provide context on priorities. We draw conclusions on what mechanisms could balance practicability, acceptability and effectiveness in the short term, and how the approach could be developed in the longer term.

The underlying message is that mitigation in the sector is both different from, and in many ways more challenging than, mitigation in other sectors of the economy. However, it is important that this message should not be interpreted as a call for the AFOLU sectors not to be tackled as a priority in mitigation policy. As the Committee on Climate Change has pointed out, most recently in its 2018 progress report[1], progress in reducing emissions in the agriculture sector has been disappointingly slow, with even cost-effective emissions reductions not being delivered; and a lack of action on forestry has led to a flat-lining of net carbon sequestration. The current policy debate on moving towards a net zero emissions target in the UK and in other developed economies, in order to deliver the 1.5°C maximum warming ambition of the Paris Agreement, almost by definition requires a policy focus on land use and sequestration, and reduces the scope for any sector to avoid the need for deep emissions reductions. Early progress on mitigation in the AFOLU sectors is essential both in its own right, and in order to generate early learning on mitigation techniques and policy options, leading to improved cost-effectiveness of mitigation.

Our analysis below identifies the main areas of mitigation potential in the sector, looking at the arable and livestock sectors, at soil carbon sequestration in agriculture, and at forestry mitigation options. It examines experience with existing decarbonisation policy frameworks, both in the UK and elsewhere, and outlines the sector-specific challenges. It then addresses the main categories of potential additional policies to incentivise emissions reductions and sequestration, including through building a clearer link to other sectors of the economy through carbon pricing mechanisms, looking at the practical challenges, including those associated with monitoring, reporting and verification. Finally, it presents a comparative overview of the strengths and weaknesses of each, both in terms of links to decarbonisation policy in the wider economy, and practical considerations for the AFOLU sectors; and recommends a potential policy mix, and ways in which that mix could develop over time in order to build connections with wider economy mechanisms and facilitate a cost-effective decarbonisation pathway for the UK economy as a whole.

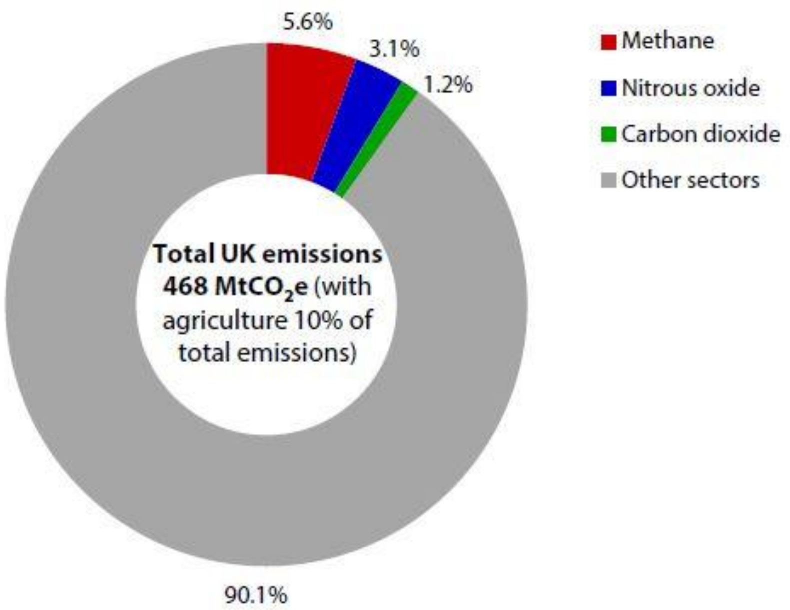
[1] Committee on Climate Change, "Reducing UK Emissions – 2018 Progress report to Parliament", 2018

2 Context

Agricultural land accounts for 71% of the UK's land area, and woodland accounts for 13%, a much lower proportion than most other EU countries except Ireland. Of the UK's total agricultural land 58% is permanent grassland, 35% is under crops and 5.5% is woodland, but the distribution of different types of land use varies significantly between the four UK countries, and particularly between England and the other three. For example:

- arable cropping and horticulture use 54% of the farmland in England, but less than 5% in Wales and Northern Ireland.
- land designated as 'Less Favoured Areas' is characterised by less fertile soils with limited agricultural potential and below average economic returns. This designation applies to 84% of the agricultural area in Scotland, 80% in Wales and around 70% in Northern Ireland but only 16% in England where the designation applies to significant tracts of the uplands in the north of England and some in the south west.
- woodland in the UK is also unevenly distributed, occupying 10% of the total land area in England, 15% in Wales, 19% in Scotland and 8% in Northern Ireland.

Figure 1: Agriculture GHG emissions as share of UK total (2016); Source: BEIS (2018) Final UK greenhouse gas emissions national statistics 1990-2016, as presented in Committee on Climate Change's 2018 progress report.



The UK's inventory of greenhouse gas emissions looks at emissions from the land sectors in two areas: agriculture emissions, and net emissions from land use, land use change, and forestry (LULUCF). Agriculture emissions, at 46.5 $MtCO_2e$ in 2016, account for around 10% of the UK's overall greenhouse gas emissions; a proportion which has been steadily increasing as decarbonisation gathers pace in other sectors. Land use, land use change and forestry is a net sink for the UK, sequestering 14 $MtCO_2e$ in 2016. The agriculture and forestry sectors have not been actively addressed by Government policy on climate mitigation, and have therefore not faced significant climate mitigation economic incentives. In England, a voluntary action plan was agreed between Government and representatives of the agriculture industry[2], focused mainly on win-win mitigation opportunities which could reduce emissions and help business profitability. A 2016 review[3] concluded (generously) that progress had been made but that more remained to be done, noting that the Government's policy for the sector was to continue with a voluntary approach, with Government help provided in identifying the most effective abatement methods. The Committee on Climate Change has criticised the lack of progress, noting in its 2018 report that:

> "Stronger policies are required to meet ambition by England and the devolved administrations in these sectors to 2020 and beyond."

The main policy intervention in agriculture has been payments under the EU Common Agricultural Policy, where UK exercise of national discretion has emphasised environmental public goods, including climate mitigation, particularly through agri-environment-climate payments, but also through "greening" requirements on subsidy payments. However, targets for mitigation have not been set in any part of the UK. Government policy on the agriculture sector post-Brexit is still being developed, with current legislative proposals before Parliament to give powers for expenditure focused on the delivery of public goods. The Government has identified the potential for a more environmentally-focused agriculture expenditure system than the CAP, identifying climate mitigation as one of 6 public goods which could underpin future agriculture policy, and noting in its 2018 "Health and Harmony" White Paper[4] that:

> "It remains incredibly important that we continue to reduce carbon emissions from the farming sector"

and that

> "Land management could play a pivotal role in responding to climate change by increasing the ability of farmland and the countryside to sequester carbon".

In the forestry sector, the CCC's 2018 progress report notes that "a lack of action on forestry has led to a flat-lining of net carbon sequestration from forests over the recent past". The Government's most recent (2013) policy statement on forestry[5] placed little emphasis on mitigation, although the 2018 25-year plan on the Environment makes it clear that a programme of forestry and woodland expansion will be set squarely within broader Government decarbonisation policy.

There is thus a gap between on the one hand the need for mitigation action in order both to deliver current carbon budgets, and to ensure progress towards the net zero target currently under examination, and on the other hand the level of Government action. In particular, while recent strategy documents have emphasised climate mitigation, Governments across the UK have not set clear expectations of the level of net abatement they want to see from the AFOLU sectors. This report looks at the options for a more ambitious approach, including carbon pricing options, and how they could be linked to mitigation policies and market drivers in the wider economy.

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[2] http://www.cfeonline.org.uk/home/about-us/greenhouse-gas-action-plan/

[3] "The Greenhouse Gas Action Plan for Agriculture: Review 2016", Defra, 2016

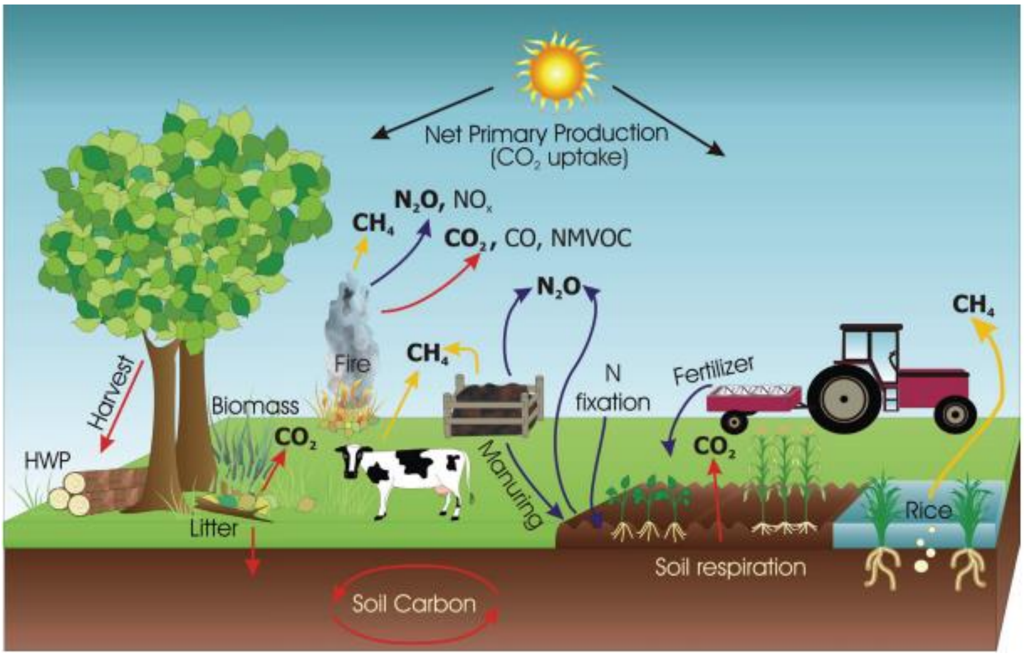
[4] Defra, 2018, "Health and Harmony: the future for food, farming and the environment in a Green Brexit", Cm 9577

[5] "Government Forestry and Woodlands Policy Statement", Defra, 2013. The emphasis of the then Secretary of State, Owen Paterson, clearly differed significantly from that of the current Secretary of State, Michael Gove.

3 Summary of abatement potential

Abatement potential of the AFOLU sector in the UK is influenced by the scale and distribution of different agricultural and forest land uses and land management systems, which in turn are determined to a significant extent by the variation in soil types and climatic conditions.

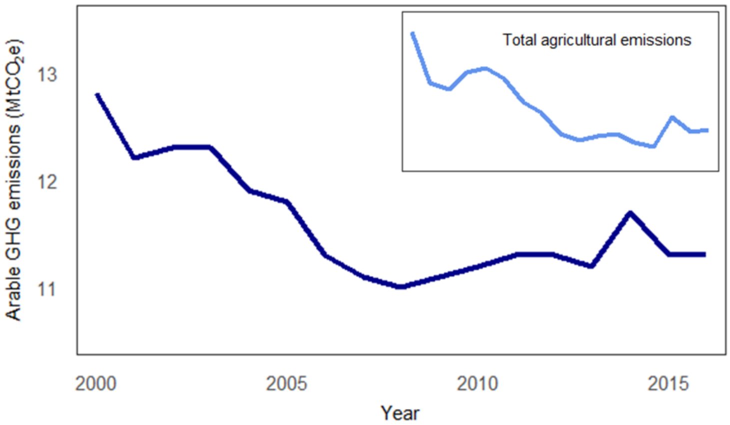
Figure 2: Overview of carbon pools and GHG fluxes managed by farmers and foresters. Source: IPCC 2006 GPG AFOLU (Introduction).



3.1 Agricultural emissions reduction: arable

Emissions from arable farming account for over a quarter (27%) of total UK agricultural[6] emissions. While emissions in this sector have fallen by 12% since 2000, in more recent years this decline has slowed and stabilised, with emissions now 2% higher than in 2008 (Figure 3).

Figure 3: Total GHG emissions from the arable farming sector in the UK. Inset shows overall trend for agriculture during the same period. Source: BEIS (2018) Final UK greenhouse gas emissions national statistics 1990-2016.



[6] Note that we focus in this report on emissions from land management, and not energy use in agriculture.

The vast majority of greenhouse gas emissions in the arable sector are in the form of nitrous oxide (N_2O); a more powerful greenhouse gas than either carbon dioxide (CO_2) or methane (CH_4). Nitrous oxide emissions result primarily from microbial activity (nitrification and oxidation) in soils following the addition of synthetic and natural nitrogen fertilisers.

Emissions from the arable sector can be reduced by reducing total fertiliser application and improving the efficiency of their use. For example, nitrification inhibitors slow microbial activity, allowing a greater proportion of applied nitrogen to be taken up by crops (see Table 1). In addition, actions to increase soil carbon sequestration can also contribute to climate mitigation by preserving existing carbon stores in soil and biomass (see 3.3; cross-cutting actions highlighted in grey). Estimating the potential emissions impact of these measures is challenging, and the scope of this project has not included a detailed analysis. However, to give an indication of scale, recent research by CEH for the Committee on Climate Change[7] suggests that high uptake of nitrogen use efficiency measures could reduce emissions by 1MtCO_2e a year by 2050.

Table 1: Key actions to reduce emissions in the arable farming sector

Practice	Explanation	Mode of action
Nutrient management plans	Identify actions to improve nutrient efficiency	Reduces total fertiliser application and residual soil nitrate, lowering the risk of nitrous oxide emissions
Use of nitrification inhibitors	These compounds slow the conversion of nitrogen from ammonium to a plant-available form	Increases the efficiency with which crops use nitrogen, reducing nitrous oxide emissions and leaching of nitrate
Biological nitrogen fixation	Include nitrogen fixing crops (legumes) in crop rotations or grass swards	Reduces total fertiliser application and residual soil nitrate, lowering the risk of nitrous oxide emissions
Improved nitrogen efficiency and precision application	Improving efficiency to reduce overall fertiliser use; e.g. by matching inputs more accurately to field conditions	Reduces total fertiliser application and residual soil nitrate, lowering the risk of nitrous oxide emissions.
Carbon auditing tools[8]	These tools help to produce a breakdown of farm emissions sources	Highlights emissions hotspots; indicating options to reduce emissions
Minimum or low tillage	Crops are seeded directly into the remains of the previous crop without ploughing. Requires specialist machinery.	Reduces use of agricultural machinery and therefore fuel use. Protects soil structure, maintaining soil organic carbon content
Soil management plans	Outline a framework to address the risk of soil erosion	Protects soil structure, maintaining soil organic carbon content.

[7] Centre for Ecology and Hydrology, 2018 "Quantifying the impact of future land use scenarios to 2050 and beyond"

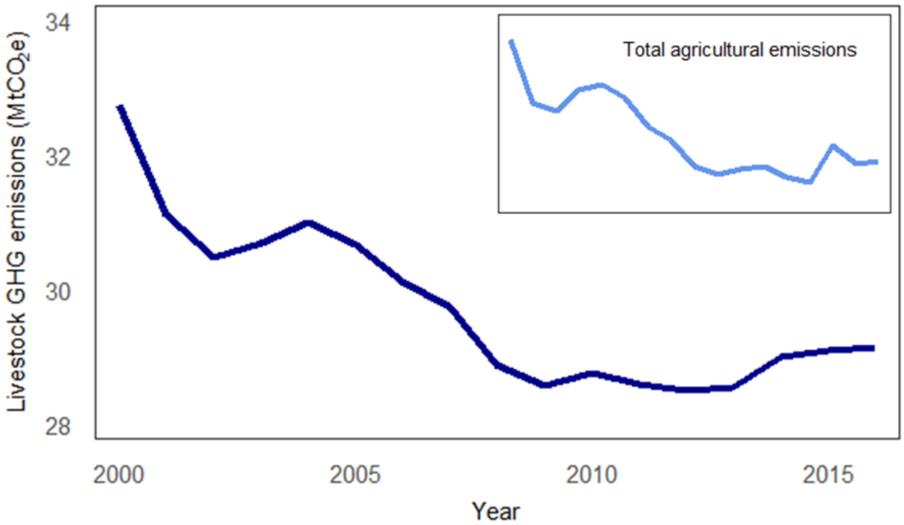
[8] For example, the carbon audits supported under Scotland's Farm Advisory Service – see https://www.fas.scot/carbon-audits/

Catch and cover crops	Reduce the area/duration of bare fallow by growing fast growing crops between main crop plantings	Protect soil structure, maintaining soil organic carbon content. Reduce nitrous oxide emissions during the fallow period.

3.2 Agricultural emissions reduction: livestock

Livestock farming accounts for the bulk (70%) of emissions from the agricultural sector. These emissions are primarily in the form of methane (CH_4) from enteric fermentation in ruminant livestock, which alone comprise more than half (53%) of total agriculture and forestry emissions in the UK. Manure storage and processing also accounts for considerable emissions of methane and nitrous oxide. Livestock emissions in the UK have fallen by 11% since 2000, but as seen in other agricultural sectors, this decline has not been maintained, and emissions have been stable since around 2008 (Figure 4).

Figure 4: Total GHG emissions from livestock farming. Inset shows overall trend for agriculture during the same period. Source: BEIS (2018) Final UK greenhouse gas emissions national statistics 1990-2016.



Emissions from livestock farming can be reduced by increasing the efficiency of production through improved livestock health and/or altered feeding or husbandry practices. Some key mitigation practices for the livestock sector are set out in Table 2. These techniques could have a significant impact on emissions (up to 30% reduction estimated at global level by the FAO) without reducing overall production volumes, if progressively introduced over a period of years. However, ensuring uptake is challenging. In much the same way as energy efficiency improvements in the building sector face behavioural barriers, despite providing economic operators with clear benefits, production efficiency improvements in the livestock sector with carbon benefits can be difficult to achieve.

The impact on emissions of the measures depends critically on the production choices made by the sector; one response to improved efficiency could be to increase production of meat and dairy products, including for export (we address below the important issue of measures to address UK consumption). The CEH research referred to above[9] suggests that a high ambition scenario could see a 10% reduction in enteric emissions per animal. If this were over time combined with a 10% reduction in livestock numbers it could generate an annual saving in enteric digestion emissions of around 4 $MtCO_2e$ a year, together with a smaller reduction in manure management emissions.

[9] See footnote 7 above

Table 2: Key actions to reduce emissions in the livestock farming sector

Practice	Explanation	Mode of action
Health planning and disease management	Preventing and rapidly treating common livestock diseases	Disease reduces productivity and increases emissions associated with each unit of output. Preventing and treating disease therefore improves efficiency and reduces overall emissions
Use of sexed semen for breeding dairy replacements	Sorting dairy bull semen to produce 90% female calves	Decreasing the number of calves born from dairy bulls will result in more calves born from beef bulls. These beef-dairy cross breeds will be more suitable for beef production, increasing overall efficiency
Breeding lower methane emissions	Breeding ruminants with lower methane emissions per unit of output	Decreases methane emissions from ruminants, and therefore the emissions intensity of ruminant products
Feed additives in ruminants	Additives may increase ruminant performance or reduce conversion of carbohydrate to methane	Both increasing performance and reducing methane production directly reduce the emissions intensity of ruminant products as above
Precision feeding strategies	Matching diets more closely to livestock requirements	Reduces excretion of excess nitrogen by livestock, therefore decreasing nitrous oxide emissions from excreta and manures
Manure management	Practices such as reducing storage time, covering manure and avoiding straw/hay bedding	Minimising storage time and covering during storage slow the rate of nitrous oxide emissions, while avoiding straw/hay bedding prevents additional carbon inputs contributing to methane emissions

3.3 Soil carbon sequestration

The abatement potential of soils through improving carbon sequestration and storage depends on the organic matter (carbon) content of different soil types and the way in which these are managed. The UK has a wide range of soil types used for agriculture, from peat soils with high carbon content, through mineral soils with varying carbon levels which may be used for permanent grassland or arable, to easily cultivated and free-draining arable soils. Soil erosion affects an estimated 17% of land in England and Wales, with a loss of around 2.2 million tonnes of soil every year (Environment Agency, 2005), while soil degradation costs more than £1bn a year. Nearly half of these costs (45%) are linked to the loss of soil organic matter and 17% to erosion. For all soil types optimal carbon management is focused firstly on preventing loss of soil carbon through oxidation of soils exposed to the air (e.g. during ploughing) and limiting the risks of soil erosion; and secondly on improving and maintaining soil carbon content and sequestration potential.

Arable soils: Land management to improve the carbon content of arable soils also contributes to improving the water infiltration and storage capacities of the soils. In the longer term it also improves the inherent fertility of the soils. In arable cropping systems which are entirely annual crops, the soil is cultivated every year (to control weeds, incorporate straw and provide a seedbed), leaving it exposed to the air for variable periods of time until the next crop is sown. Management options to conserve soil carbon in these systems are set out in Table 3 below.

Permanent grassland soils: in agricultural policy terms the definition covers both intensively managed grassland (which is ploughed up and reseeded at intervals), and rough grazing areas, often on poorer quality agricultural land, which are rarely if ever ploughed. Grassland sequesters carbon both in the biomass above ground and in the soil, through the build-up of plant roots and decaying plant material. The sequestration potential is inversely linked to frequency of soil disturbance, as described above, but is positively correlated with biomass production above ground (Martineau). Productivity of grassland on the more intensively managed soils relies on levels of fertiliser application, especially N, which in turn increases the risk of NO_2 emissions, especially from wet soils. Management options to conserve soil carbon in these systems are set out in Table 3 below.

Peat soils

Peat soils are defined as having more than 30% soil organic matter in the upper soil layer, formed over thousands of years from decaying plant material in wet conditions. Some mineral soils with 20-30% soil organic matter are also classified as 'carbon rich'. Draining these soils and exposing them to air leads to high levels of carbon loss through oxidation and erosion. It is estimated that actively eroding peat loses 2.6 tCO_2eq/ha/yr (Smyth et al 2015). Fully rewetting peat soils allows the process of carbon sequestration to resume, but generally precludes their use for productive agriculture or forestry. There are two main types of peat soils in the UK. Acid peat soils in uplands of the west and north-west of the UK have mostly been drained for use as permanent pastures and rough grazing (e.g. the northern Peak District) or in some case afforestation. Fen peat soils are very fertile and found principally in East Anglia and parts of western England where they are used for arable cropping and grassland (and also commercial 'strip mining' for horticultural use). There are a range of management options to conserve and sequester soil carbon in peat soils (see Table 3).

Table 3: Examples of actions to increase sequestration in arable, grassland and peat soils

Soil type	Practice	Explanation	Mode of action
Arable	Addition of organic matter	Using organic fertilisers (e.g. manures, compost); incorporating straw, other post-harvest crop residues and cover crops at the next cultivation	Increases inputs of organic carbon to soils
Arable	Temporary grassland or other forage crops	Growing temporary grassland or other forage crops for two or more years within the arable rotation	Protects soil structure and increases organic carbon inputs, encouraging sequestration
Arable	Permanent grassland	Creating permanent grassland	
Arable	Catch and cover crops	Reduce the area/duration of bare fallow by growing fast growing crops between main crop plantings	
Arable; grassland	Minimum or low tillage	Crops are seeded directly into the remains of the previous crop without ploughing. N.B. Requires specialist machinery and zero tillage systems in the UK climate can have weed problems	
Grassland	Avoiding compaction	Minimising physical damage and disturbance (e.g. from livestock or machinery)	Protects soil structure
Grassland; peat	Permanent vegetative cover	Maintaining or reinstating permanent vegetative cover	Protects soil structure and increases organic carbon inputs
Peat	Avoiding drainage or afforestation	Drainage and afforestation dry out peat soils, causing the loss of stored carbon, increasing fire risk, and preventing continued sequestration.	Maintains water levels needed for peat formation
Peat	Paludiculture	Production of biomass (reeds, energy crops, short rotation coppice) and specialist products such as *Sphagnum* moss for packaging) from peatlands	Enables continued peat formation

3.4 Forestry carbon sequestration

The mitigation potential of forests depends on the type of tree crop, the time taken to reach maturity (which can vary from 20 to >100 years) and the age-structure of the forest because sequestration potential is highest in younger trees and declines over time. The end use of the harvested biomass and wood products is also important, for example whether as a feedstock for energy generation or used to substitute for more carbon intensive products such as building materials. Management to conserve and sequester carbon in forests includes afforestation and improved woodland management (see Table 4).

Recent analysis by the Committee on Climate Change, based on research by CEH, looked at the potential mitigation benefits of a high ambition scenario for tree planting, with the results shown in Figure 5 below. The time profile for the mitigation benefits of afforestation is an important factor to bear in mind.

Figure 5: Net carbon sequestration of high ambition of tree planting by type of forest, 2017-2100. Source: Committee on Climate Change, "Land use: Reducing emissions and preparing for climate change", 2018

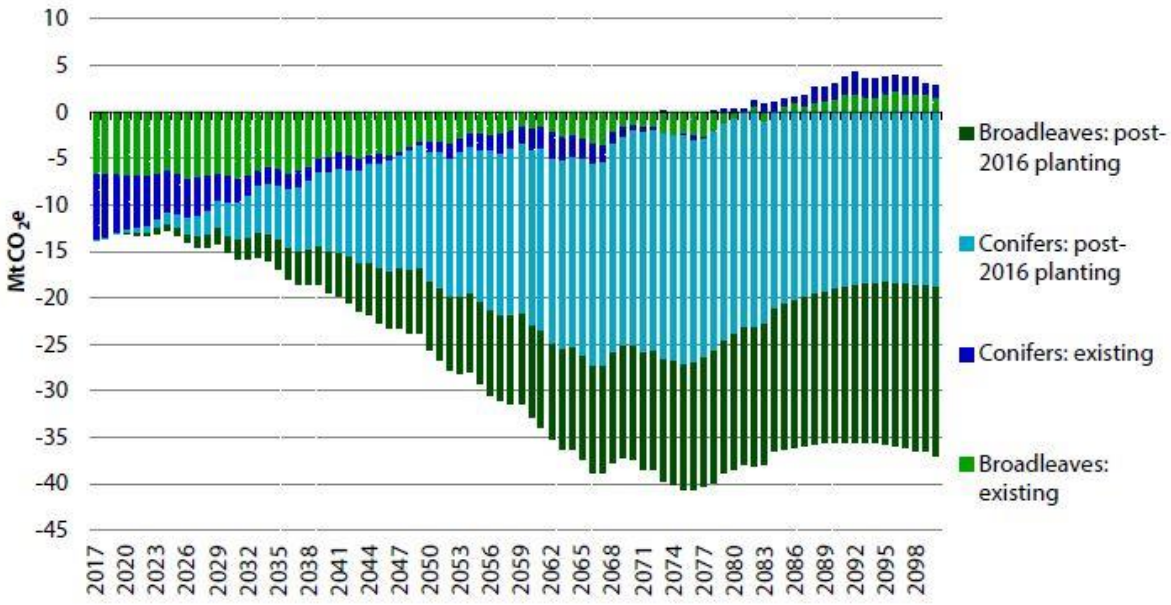


Table 4: Examples of actions to increase sequestration through forestry

Practice	Explanation	Mode of action
Woodland creation	Woodland creation on agricultural or other land	Increasing sequestration through biomass growth and soil protection
Woodland protection	Protection from conversion to other uses, soil erosion (for example during timber extraction), pests and diseases and fire	Protects soil structure and enables continued sequestration in soils and biomass
Improved management	Improved diversity of species and age classes; use of genotypes resistance to disease	Secures long-term sequestration potential of UK forests

3.5 Bioenergy and other uses of biomass

A basic principle of the inventory for carbon sequestration in forests is that harvesting is assumed to lead to instant oxidisation of the carbon stored in a tree. The UK inventory then separately records the carbon stored in harvested wood products in order to estimate this carbon sink, by ascribing different assumed service lives to different categories of product, from 35 years for sawn timber, to 2 years for paper[10]; use as fuel is, again, assumed to lead to instant oxidisation. This means that the mitigation benefit of bioenergy use is in replacing fossil fuels; as the UK's energy mix decarbonises, the mitigation value of biomass use will decline accordingly (as with renewable energy sources). Bioenergy policy should therefore be considered mainly as an element in energy policy, with the caveat that its land use implications (for example, increasing the afforested area in the UK) need to be considered carefully[11]. Harvested wood products, however, have benefits both in terms of the carbon sink they provide in their own right (while noting that the carbon storage is more short-term than carbon in unharvested forests), and in terms of their potential to replace less resource- and carbon-efficient materials. A further benefit is the potential for appropriate use of harvested wood products to create economic returns for forest management. There is thus a role for policies to encourage sustainable use of harvested wood products in replacement of other materials.

3.6 Consumption

A final and important consideration for emissions in the agriculture sector in particular is the link to consumption. A reduction in emissions through a significant reduction in production of meat and dairy products in the UK, for example, would reduce the UK's emissions as recorded to the UNFCCC in its inventory, but would not necessarily lead to a real reduction in global emissions: if UK levels of consumption of meat and dairy remained unchanged, we would simply be exporting the emissions associated with production to other economies (and, if the marginal units of production resulted from deforestation, with potentially significant risks of higher levels of net emissions overall). Equally, UK production remaining constant while UK consumption of livestock products decreased would imply that the UK was exporting to other economies, with a beneficial impact on their net emissions.

There are therefore strong arguments, as part of a wider UK strategy of reducing the overall carbon footprint of the economy, for demand-side measures. The Committee on Climate Change's 2013 report on the UK's carbon footprint[12] noted the potential for behavioural measures, including carbon labelling, but acknowledged that the emissions impact of these was likely to be limited. Additional options relevant to food consumption include taxation, particularly of relatively high-emissions products such as meat and dairy. While the political feasibility of such options has been assumed to be low, the debate may develop over time. Health co-benefits could also be a relevant driver; a recent report which achieved significant publicity[13] focused exclusively on the health benefits of a tax, and earlier research has suggested that health justifications for taxes on food are significantly more likely to achieve wide acceptance than environmental ones.

[10] See Annex 3 to the UK greenhouse has inventory, section A.3.4.10 Harvested Wood Products,

[11] And, if imports of biomass as fuel come from areas of the world economy which are not currently subject to carbon constraints (for example, wood pellet imports from the US), it is inaccurate to treat the biomass use in energy as effectively carbon emission free.

[12] "Reducing the UK's Carbon Footprint", Committee on Climate Change, April 2013

[13] "Health-motivated taxes on red and processed meat: A modelling study on optimal tax levels and associated health impacts", Springmann et al 2018

4 The evidence on policy mechanisms

We examine in section 5 below some of the main options potentially available for incentivising greenhouse gas emissions reductions or sequestration in the agriculture and forestry sectors. In this section we present some evidence of the approaches that have been adopted, either in the UK or elsewhere, and the evidence on their impacts. The theoretical options are similar to those in other sectors, but the specific challenges (both in terms of monitoring, and in terms of the economic structure of the land use sector) are outlined in section 4.2 below. The current approach adopted in the UK is essentially a combination of voluntary mechanisms and public expenditure support under the CAP[14]. Other theoretical possibilities include:

- application of a carbon price through trading, either through
    - imposing a cap on the land use sector itself, or
    - allowing credits from the land use sector to be used to demonstrate compliance in other sectors;
- application of a carbon price to the agriculture through taxation, either
    - of agricultural activities themselves, or
    - of the consumption of agricultural products; and
- the use of regulation (for example, to ban or discourage activities which emit greenhouse gases unnecessarily).

4.1 Approaches and incentives adopted or proposed in the UK and elsewhere

4.1.1 Overview of agriculture sector abatement options

Regulatory measures and incentives to deliver mitigation and other services through the agricultural sector in Europe mainly come from the EU's Common Agricultural Policy (CAP). The CAP has two main divisions: Pillar one which focuses on direct support of farmer incomes and Pillar two which deals with the rural development aspects of the policy. Opportunities to deliver abatement are found in both of these, as well as in cross-compliance measures (in particular Good Agricultural and Environmental Conditions, or GAECs) which apply across both pillars (Table 5).

Table 5: Key measures of the Common Agricultural Policy that can deliver mitigation

CAP's Pillars	CAP measure	Description of the measure (EU level)	Potential effect on mitigation	Implementation of CAP measures in UK (England)
Pillar 1 measures	Greening payment: Crop diversification obligation	Over given area thresholds 2 or 3 arable crops must be grown	Maintains and enhances soil organic carbon content. If legumes are introduced to rotations, likely to reduce nitrous oxide emissions	Farms with >10ha must grow at least 2 crops, and farms with >30ha must grow at least 3. The largest crop must take up no more than 75% of the arable area
	Greening payment: maintenance of Permanent Grassland ratio	Ratio between permanent grassland and cultivation must not decline by >5%	Prevents loss of soil organic carbon content and promotes further sequestration	Implemented across England not at farm level; the proportion of permanent grassland compared

[14] While the focus of the Common Agricultural Policy on climate mitigation has increased significantly over the last decade, with agri-environment measures being recast as agri-environment-climate measures, and climate mitigation specified as one of the objectives behind the "greening" of subsidy payments, there is significant scope for a new UK approach to agricultural payments to deliver more mitigation, and to set clearer targets for the impact of expenditure.

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				to cultivated area must not fall below 5% across England
	Greening payment: protection of Environmentally Sensitive Permanent Grassland	Designated areas of ESPG must be protected from disturbance	Prevents loss of soil organic carbon content and promotes further sequestration	Permanent grassland covered by the Wild Birds or Habitats Directives cannot be cultivated
	Greening payment: Ecological Focus Areas	Farmers with >15 ha of arable land must apply EFA options covering ≥5% of the total arable area.	Reduces loss of soil organic carbon content by protecting soil structure; encourages carbon uptake by biomass and promotes sequestration in soils	EFA options available to farmers in England include fallow land; buffer strips and field margins; catch and cover crops; nitrogen fixing crops; hedges and wooded strips
Cross-compliance measures (horizontal)	GAEC 1	Establish buffer strips along water courses	Buffer strips are likely to protect soil structure, preventing erosion and maintaining soil organic carbon content.	Maintain buffer strips. Ploughing or application of organic or inorganic fertilisers, pesticides or herbicides prohibited within a certain distance of a watercourse
	GAEC 4	Maintain minimum soil cover	Prevents loss of soil organic carbon content and promotes further sequestration	Maintain minimum soil cover all year round. Cover options include all types of crops, grass and forage; nitrogen fixing crops; game cover and crops planted for biodiversity; trees; stubbles and crop residues
	GAEC 5	Maintain minimum land management reflecting site specific conditions to limit erosion	Prevents loss of soil organic carbon content and promotes further sequestration	Put measures in place to limit soil and bankside erosion caused by cropping practices and structures, livestock management, wind, vehicles and others
	GAEC 6	Maintain soil organic matter level through appropriate practices. Ban on burning arable stubbles.	Prevents loss of soil organic carbon content and promotes further sequestration. Prevents emissions from burning.	Maintain soil organic matter through appropriate practices. Farmers cannot plough, cultivate or intensify species-rich and semi-natural habitats.
	GAEC 7	Retention of landscape features	Reduces loss of soil organic carbon content by protecting soil structure; encourages carbon uptake by biomass and promotes sequestration in soils	No pesticides, herbicides, fertilizer, or tillage within a certain distance of a hedge. Hedgerow removal not permitted in most circumstances; limits on cutting timing. A licence is necessary to cut down a tree.
Pillar 2 measures	Measure 4	Investment in physical assets	Can fund equipment which reduces emissions; e.g. for manure storage; bioenergy; postharvest storage and processing; ecosystem restoration.	Supports businesses seeking to invest in innovative practices and new technologies that improve sustainability and productivity. Investments will support improved resource efficiency or animal health and welfare.
	Measure 10	Agri-environment-climate measures	Range of measures focussed on taking land out of production, changing management practices and improving wildlife habitats.	Measures specified for different landscape types. These contribute to biodiversity, water quality, climate mitigation and adaptation, soil, and flood management objectives. Targeted at key local catchments.

***Box 1:** Examples of implemented CAP measures that can deliver agriculture sector mitigation*

In **Italy** an agri-environment-climate programme supports integrated production, addressing the GHG emissions priorities of the Emilia-Romagna region. These are to reduce emissions from agricultural production and improve the efficiency of agricultural inputs used. The programme should lead to a reduction in fertiliser use and hence reduce N_2O emissions.

In **Slovakia** an investment in physical assets programme supports construction and repair of livestock housing and breeding of livestock using new technologies for emissions reductions.

In **the UK** cross-compliance has improved compliance with the Nitrates Directive by designating revised "Nitrate Vulnerable Zones", establishing a range of mandatory measures to reduce nitrate pollution in these zones and a Code of Good Practice outside the zones.

Source: Hart et al., 2017. The consequences of climate change for EU agriculture. Final report to the European Commission, DG Internal Policies, IEEP, London

4.1.2 Forestry sector

More than a quarter of the total UK woodland area is owned by the devolved governments, and managed on their behalf by the Forestry Commission in England and Scotland, and the equivalent agencies in Wales and Northern Ireland. Here we consider mainly the privately owned woodlands which range from sizeable forests (particularly in Scotland) managed by forest companies to small woodlands on farmland. The main policy mechanisms to **prevent deforestation** is the regulatory requirement to obtain a licence to fell timber (other than very small quantities), which is usually accompanied by replanting requirements. **Creation of new woodland** has been identified as the mitigation option with greatest potential for the UK forest sector. This is less regulated, except in the case of large areas of afforestation where an Environmental Impact Assessment is required. Afforestation on privately owned land almost always involves support from public funding to cover high initial investment costs, the low rate of return on capital for many years and, in the case of better quality farmland, the opportunity costs. Funding (around £80m a year in total) comes from the four UK countries' woodland creation and management schemes, co-financed by EU agricultural funds as part of the CAP Rural Development Programmes (RDP). **Improved environmental management of woodlands** is supported in the same way, typically by capital grants and annual payments over a number of years. All such funding requires the woodland to be managed to the UK Forest Standard for sustainable forest management. The governments also fund forest advisory services for private owners. In 2017-18 a total of 9,000 hectares of newly created woodland and 14,000 hectares of woodland restocking were reported in the UK in 2017-18 (some of the latter will have been in state-owned forests).

***Box 2:** Examples of implemented CAP measures that can deliver forestry sector mitigation*

In **England** the current RDP supports investment to modernise forestry technologies, improve the resilience, environmental value, mitigation potential and biodiversity of existing forests, and to create new woodland. Applicants for planting grants must provide a Woodland Creation Plan, demonstrating that they have selected species appropriate for the site conditions and objective.

In **Scotland,** £252 million of RDP funding has been allocated to the Forestry Grant Scheme to support woodland creation and the sustainable management of existing woodlands. The Scottish Government is committed to increasing the current annual woodland creation target of 10,000 ha to 15,000 ha by 2024/25, and is currently consulting on its Forest Strategy 2019-29[1].

In **Wales,** applicants for the RDP Glastir Woodland Creation Scheme can view an online map showing if their land has been identified as a 'woodland opportunity' area[1]. Applicants for the Native Woodland Carbon planting grant must register their planting with the Woodland Carbon Code.

Source: Hart et al., 2017. The consequences of climate change for EU agriculture. Final report to the European Commission, DG Internal Policies, IEEP, London

Mitigation associated with woodland creation can be difficult to estimate, as it depends on species, soil quality, and management choices (which should balance other public benefits, including public access, biodiversity, and landscape, alongside carbon benefits). However, the Forestry Commission estimates[15] that "over a full rotation, including planting to felling, a conifer forest can sequester around 14 tonnes of carbon dioxide per hectare per year. When UK woodlands are looked at as a whole, the average is around 5.4 tonnes of carbon dioxide per hectare per year (or 1.4 tonnes of carbon per hectare per year), including broadleaved and unproductive woodlands".

4.1.3 Trading and other mechanisms covering both sectors

New Zealand has included forestry under its Emissions Trading System (ETS) since 2008. It is the only country in the world to do so. A review has determined that the policy has decreased rates of deforestation, but has only had a small effect on afforestation so far. However, this is likely to be due mainly to policy uncertainty and depressed carbon prices[16]. As of 2018 the government is considering options to improve the policy's effectiveness[17], including measures to encourage new tree planting, recognition of sequestration in harvested wood products, and improvements to the compliance regime. Agriculture had originally been planned for inclusion in the ETS from 2015[18], but this decision was reversed before implementation due to concerns over carbon leakage, lack of abatement opportunities and lack of available data[19]. The inclusion of agriculture in a revised ETS is now foreseen by the present government; consultations are under way by the Interim Climate Change Committee regarding the feasibility and details of this policy. According to the Government's coalition agreement, if the Commission determines that agriculture is to be included in the ETS, then upon entry, the free allocation to agriculture will be 95% but with all revenues from this source recycled back into agriculture in order to encourage agricultural innovation, mitigation and additional planting of forestry.

When inclusion in the ETS was being considered, the government decided to place the point of regulation at the processor level to minimise the number of participants and thereby lower administrative costs and simplify the MRV requirements. However, this approach was contested, with opponents claiming that this would make the ETS function solely as a per kilogram levy rather than incentivise mitigation activities. Under the current mandatory reporting system for agriculture under the New Zealand ETS, 80 upstream (supplier) and downstream (processor) entities are obliged to participate and report their emissions, but are not obliged to surrender allowances, due to the political concerns about inclusion of the sector.[20]

California's cap and trade system allows for up to 8% of a facility's compliance obligation to be met using purchased offsets. These must be sourced from emissions-reduction projects in U.S, and are restricted to independently verified projects in five areas including forestry, urban forestry, and dairy digesters and is developing a protocol to reduce GHG emissions from rice cultivation. For some of these project areas such as manure digesters, there has been poor uptake of offsetting opportunities

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[15] Undated advisory note "Mitigation: Planting more trees"

[16] Carver, T., Dawson, P., & Kerr, S. (2017). Including Forestry in an Emissions Trading Scheme: Lessons from New Zealand, *Motu Working Paper* 17-11, http://motu-www.motu.org.nz/wpapers/17_11.pdf

[17] New Zealand Government, A Better ETS for Forestry: Proposed amendments to the Climate Change Response Act 2002, Te Uru Rākau Discussion Paper No: 2018/02, https://www.mpi.govt.nz/news-and-resources/consultations/a-better-ets-for-forestry

[18] Kerr, S., Anastasiadis, S., Olssen, A., Power, W., Timar, L., & Zhang, W. (2012). Spatial and temporal responses to an emissions trading scheme covering agriculture and forestry: simulation results from New Zealand. *Forests*, 3(4), 1133-1156. https://www.mdpi.com/1999-4907/3/4/1133/htm

[19] Energy Systems Catapult, (2018), Policy Case Studies Rethinking Decarbonisation Incentives

[20] Energy Systems Catapult, (2018), Policy Case Studies Rethinking Decarbonisation Incentives

on the project developer side due to non-financial market barriers (including concerns in the dairy industry about economic risks and the management attention required for operation).

The **Clean Development Mechanism (CDM)** is an international offsetting mechanism established under the Kyoto Protocol in which developed countries can invest in projects in developing countries to fulfil their emissions reduction requirements. Agriculture projects were included in the mechanism, although there is some controversy over the consequences and permanency of forestry and other land-use projects. The CDM had a number of significant problems in terms of environmental integrity and economic efficiency, but it can serve as a guide in building future systems. A key issue for policymakers to recognise is that a market-based project system such as the CDM will tend to focus investment on the cheapest opportunities for generating credits available; while this in principle should lead to cost-effective abatement choices, in practice it can mean that funds flood towards options which are over-generously treated by the scheme rules (for example, in the CDM significant funding was routed toward projects for destruction of HFC23, because of its high global warming potential, creating perverse incentives for the production of HFC 23[21], and leading to lobbying pressure from some developing economies against the use of much simpler regulatory mechanisms for tackling HFC 23 emissions). While rules can be tightened to address unintended consequences, for example through a process such as the CDM methodologies panel, which reviews the rules under which credits are allocated, such changes usually require time to implement (recognising legitimate business certainty needs), with the potential for significant damage in the meantime.

4.2 Analysis of key challenges in developing policy options

4.2.1 Monitoring, reporting and verification issues

A key challenge for all policy options is the inherent difficulty in measuring and verifying emissions, and emissions reductions. Significant progress has been made in improving the UK agriculture inventory[22], with estimates of emissions now reflecting a much more fine-grained set of drivers (for example, rather than just an approach based on multiplying numbers of livestock by a single emissions factor, the inventory now reflects data on age, breed, and diets). However, the estimates of agricultural emissions are based on data from the annual June Survey of Agriculture and Horticulture, which in turn is based on a sample of farm holdings across the UK. While it is a significant improvement in the accuracy of estimating UK emissions, it is nevertheless still an estimate. Changes in activity or other approaches to mitigation by individual farm holdings would affect the estimated totals only to the extent that (i) those holdings were part of the annual sample and (ii) the changes were reflected in the criteria now driving the emissions totals recorded in the inventory.

A further challenge with agricultural emissions is that the level of confidence of our scientific understanding of the emissions associated with activities or changes in activities (such as nitrous oxide emissions from the application of organic fertilisers to soils in different climatic conditions; or the impact on methane emissions of changes in ruminant diets) is much lower, and the error bars on estimates of emissions much greater, than with, say, CO_2 emissions from combustion plants. While the research work carried out as part of the UK's agricultural inventory improvement has reduced the size of the error bars, these are still significant.

For forestry, the problems are less severe, although the estimation of changes in the stock of forest carbon is made at an aggregate level, and may therefore not identify (and give credit for) changes at

[21] See Schneider (2011) Perverse incentives under the CDM: an evaluation of HFC-23 destruction projects, Climate Policy, 11:2, 851-864

[22] For further information, see the "Technical Annex: The Smart Agriculture Inventory" to the Committee on Climate Change's 2018 Progress Report to Parliament

the level of individual land holdings; and in particular may not identify and give credit for small-scale afforestation decisions, including the introduction of agroforestry, or planting of small parcels of land.

For mitigation policy in the AFOLU sector, the two principle problems are therefore that (i) mitigation activity may not show up in the UK's reported emissions, or may only show up with some delay; and (ii) the credit for mitigation activity may be difficult to attribute to the individual farm or forestry business responsible for it. Our recommendation would be to focus policy on measures which Government is confident are reducing greenhouse gas concentrations in the atmosphere, regardless of the immediate impact on the UK inventory; however, the difficulties this may create in linking measures in the AFOLU sector to measures in other sectors, and ensuring a similar level of carbon price, need to be acknowledged.

4.2.2 Lack of reliable evidence on the link between instruments and net emissions

While the inventory itself is not directly responsive to changes in farm practice on individual holdings, there is nevertheless a significant amount of data available to policymakers as a result of the high level of public intervention in the agriculture sector through the Common Agricultural Policy. A similar level of public intervention is likely to continue, albeit with new and possibly more targeted objectives, in the UK after its departure from the EU. However, in the agriculture sector, a number of limitations impede a detailed and quantitative analysis of the impact of policy instruments on net GHG emissions, as presented below. Where such analyses have been undertaken, they usually involve a substantial degree of uncertainty.

- The data collected under the CAP's reporting and monitoring framework in most cases does not enable to draw clear links between support received and the precise nature of the projects or actions funded.
- Where this information is available (e.g. operations under agri-environment-climate schemes, greening payment obligations), data that are critical for assessing the climate mitigation impacts are often not collected as part of the CAP audit and control systems[23]. For example, the data that has to be collected for the permanent grassland ratio obligation under the greening payment (see section 4.1.1) does not include information on whether or not the grassland has been ploughed and re-seeded[24]. From a climate perspective, whether ploughing took place or not would greatly impact the levels of carbon stocks. Many other types of similar climate-relevant data are currently not reported on or not at a granularity/frequency that would allow to make a judgement of a measure's impact on GHG emissions e.g. fertiliser use and application methods at holding level; tillage practices at holding level; manure management arrangements at holding level; types of livestock housing; soil maps covering carbon content and soil erosion; landscape features' incidence and management.
- The abatement potential of a mitigation action can greatly vary depending on a range of factors, e.g. current baseline (i.e. current farm practice), soil/livestock types to which it is applied, other environmental (e.g. weather conditions), biogeographical and socioeconomic factors (e.g. machinery/equipment used).

4.2.3 Fragmented nature of the sector

In addition to the intrinsic problems of measuring emissions and sequestration from natural and semi-natural systems, the nature of land management businesses is very different to the ownership of relatively large installations in the sectors covered by the EU ETS. In 2010, there were an estimated

[23] In particular the EU's Integrated Administration and Control System (IACS) and its associated Land Parcel Identification Systems (LPIS), which are systems implemented by all Member States to manage and control the way CAP payments are made to EU farmers.

[24] These practices are allowed under the permanent grassland definition.

187,000 farm holdings across the UK[25]; and while the number is likely to have reduced since then in line with a long-term trend towards consolidation of holdings, it means that predominantly the sector has the characteristics of SMEs and micro-businesses. This has implications both for sectoral responsiveness to policy initiatives, and for the collection of reliable data. In practice, land-based businesses have been very sensitive to changes in public policy, because of the high levels of public subsidy and incentives available. However, policy-makers are faced with a trade-off between the wide range of policy objectives they might want farms to address, the sophistication of the incentive mechanisms applied, the transaction costs for public authorities in delivering more targeted and cost-effective incentives, and the limited management time at the disposal of farm businesses to respond to those incentives.

4.2.4 Competition and synergies between AFOLU abatement options, and with other land use and land management options

Some AFOLU options have a significant opportunity cost, for example afforestation of farmland, converting arable soils to permanent grassland and rewetting arable peat soils. Soil carbon measures improve soil fertility and protect soils from erosion, and limiting NO_2 and CH_4 emissions can have long-term benefits to the efficiency and productivity of the farm business. In the wider environmental policy context many of the potential abatement measures discussed here have synergies with other environmental policies, for example water quality (NO_2 reduction), flood risk management (forestry, peat rewetting), soil protection from erosion, and biodiversity (native woodland planting) but in practice the synergies are highly dependent on location and type of action. There are also potential conflicts, for example intensification of grassland management to sequester carbon can threaten species rich semi-natural grasslands.

In addition, there are also potential mitigation trade-offs between competing land uses. For example, afforestation, or indeed interventions like construction of wind farms, creates an immediate soil carbon loss, which is gradually offset by the sequestration of carbon in trees (or by reduced emissions from the energy generation). At an aggregate level, conversion of farmland to forestry may lead either to reduced UK production (and a consequent exporting of the carbon footprint of UK production), or to intensification of production on remaining farmland, with an impact on emissions.

4.2.5 Temporary nature of carbon sequestration

Storing carbon in growing and harvested biomass is not directly equivalent to (or as reliable as) permanently reducing emissions, because the carbon is likely to be released at some point in the future – either in a planned way, in the case of commercial forestry or bioenergy, or in an unplanned way (change of land use) fire, end of life of the plant, etc. Soil carbon measures depend on management changes by thousands of individual farmers, which may not be maintained in the long-term (for example when ownership changes or if public funding is withdrawn). The temporary nature of the mitigation potential in the AFOLU sector has implications for policies on pricing; a tonne of carbon abatement in temporary sequestration should not be treated as being equivalent to a tonne of carbon not emitted in the first place.

4.2.6 Emissions leakage risks

The consumption footprint issues identified in section 3.6 above illustrate the potential carbon leakage risks in the agriculture sector. Production decisions in agriculture markets, particularly for arable crops, can be implemented rapidly, usually without the need for major capital investments, provided downstream infrastructure is present; and even for livestock, land can be converted relatively swiftly. While this also means that shifts in production tend not to be as permanent as, for example, shifts in industries (e.g. cement) requiring significant plant investments, it means that

[25] Eurostat data

individual farm businesses are more directly exposed to competition on commodity prices. Equally importantly, the risk of adding to pressures for land conversion and deforestation by increasing UK net demand, particularly for livestock products, could mean that poorly designed UK mitigation policies lead to net increases in net global greenhouse gas emissions.

5 Possible options for emissions pricing

This section briefly examines possible options for mitigation policies in the AFOLU sector based on financial incentives. Carbon constraints could also be created – and to some extent already are – by regulatory measures (for example, requirements for improved slurry storage to comply with the nitrates directive also have benefits in terms of avoided GHG emissions). We do not examine regulatory mechanisms explicitly here, but have included them in the summary analysis of options in section 6 below.

5.1 Tradeable credit mechanisms

A carbon price could be applied to the sector either through a cap and trade system (which we explore below in section 5.2), or through a system which generated credits for mitigation action in the AFOLU sector, which could be used to meet caps in other sectors (for example, the ETS sectors). This approach is already used informally in the private sector by organisations wishing to claim carbon neutrality, which fund carbon sequestration projects in the UK or elsewhere to offset their residual emissions. We examine here what sorts of measures could give rise to credits, and the practicalities of operating such a system. A key feature of this approach is that the mitigation incentivised should be counted against the delivery of targets in other sectors, rather than in the AFOLU sector itself.

5.1.1 Measures which could generate credits

Agriculture emissions reduction measures of the kind discussed above in section 3 could be the basis for credits in future, but in some cases recording them as part of the delivery of UK targets would be dependent on improvements to the inventory categories.

More progress has been made on forest and peatland measures, including:

(i) the Woodland Carbon Code (WCC), developed and certified by the Forestry Commission[26] has created two types of tradeable credits: a Woodland Carbon Unit (WCU) is a tonne of CO_2 which has already been sequestered in a WCC-certified woodland, independently verified and can be used by UK companies to report against emissions as soon as it is purchased. A Pending Issuance Unit (PIU) is a 'promise to deliver' a WCU during a given period, based on predicted growth, which cannot be used to report against emissions until verified.

(ii) the Peatland Code is a voluntary standard for UK peatland projects wishing to market the climate benefit of peatland restoration. It sets out a series of best practice requirements including a standard method of quantification which, when validated by an independent body, will assure buyers of the verifiable climate benefit over the project duration. As currently designed it facilitates private investment motivated by corporate social responsibility, but is not intended for use in carbon offset schemes, corporate carbon reporting or to be traded on international carbon markets.

In principle, subject to addressing the monitoring, reporting and verification challenges, the mitigation practices we have identified in Section 3 above could all give rise to credits. However, a distinction may need to be drawn between those measures (for example, improved efficiency of livestock production through animal health improvements; more targeted application of fertiliser to avoid excess N_2O emissions) which have a negative cost for farm businesses, and those which provide pure public benefits in terms of carbon mitigation. Crediting the former risks significant deadweight costs;

[26] https://www.forestry.gov.uk/forestry/INFD-9NBF8Y

these can be dealt with more effectively in support from public expenditure by adjusting the amount and the nature of the public support given.

5.1.2 Requirements for policy response in other sectors

Policy in other sectors of the economy would need to be adjusted to reflect the availability of AFOLU credits. In the first place, the use of a credit system presupposes regulatory demand for credits through policy mechanisms such as a cap and trade system (which limits the carbon pricing options which would be compatible). Secondly, caps would need to be tightened and set at a level which reflected the availability of credits, and reflected the use of the cap and trade mechanism to drive both abatement in the sector to which it applied, and additional abatement in the AFOLU sector. The intrinsically temporary nature of mitigation through afforestation or soil carbon sequestration would need to be addressed, with those surrendering credit either taking on themselves, or insuring against, the risk of the carbon being lost to the atmosphere at a future date (or, more manageably, all sequestration credits being valued in regulatory terms at a discount to avoided emissions, to reflect those risks). Finally, mitigation policy in the AFOLU sector itself would need to reflect the potential demand for credits – should other mechanisms, such as public expenditure, be used to deliver only a subset of mitigation options excluded from the credit market? And how should targets for the AFOLU sector itself be set, given that the responsibility for part of its mitigation was, either potentially or in practice, now owned by the ETS sector.

5.2 Emissions trading

Implementing an emissions trading system (ETS) for the AFOLU sector faces a number of political and technical challenges. Several academic studies have shown that an ETS approach to AFOLU could theoretically be a significantly more cost effective way to reduce emissions than other policy instruments[27]. However, there is considerable uncertainty regarding the level of transaction costs in an ETS for the sector, and whether these would outweigh the cost benefits for emissions abatement. Due to the lack of real examples to study, estimates of transaction costs vary significantly.

MRV problems present a significant obstacle for market based policy instruments in the sector due both to technical challenges and the high number of participants and heterogeneous structure of the sector, including a large number of small operators (see sections 4.2.1 & 4.2.3 for details). However, the literature suggests that transaction costs could be managed in a variety of ways, especially if synergies can be found within the existing institutional set-up of the sector, for example through incorporating data gathering for emissions monitoring purposes into the monitoring associated with agricultural subsidy payments. Transaction costs would also be likely to decrease significantly over time, as has been seen in other emissions trading systems. However, brokerage fees could present a barrier to entry for smallholders.

A variety of choices can be made with regard to the design of an ETS. Forestry and agriculture would generally be treated differently.

Forests can be included in an ETS in an effort to incentivise the preservation of forest and encourage afforestation. Normally, participants earn credits for net increases in the carbon stock in forested land, and are also liable for any net decreases in the carbon stocks. A decision needs to be made regarding a baseline year for dividing forest that incurs only liability from forest that is eligible for credit. This is

[27] Godefroy Grosjean, Sabine Fuss, Nicolas Koch, Benjamin L. Bodirsky, Stéphane De Cara & William Acworth (2018) Options to overcome the barriers to pricing European agricultural emissions, *Climate Policy*, 18:2, 151-169, DOI: 10.1080/14693062.2016.1258630

equivalent to the initial allocation of units in a cap and trade system[28]. Certain areas of forest may still be designated for preservation outside of the ETS, for example old growth or native forest which may have particular value for biodiversity. Particular challenges in the forestry sector include the long time horizons involved which can make investments riskier.

In designing an ETS for agriculture, decisions need to be made regarding the level of coverage of emissions. This can be done to reduce costs, technical difficulties, and risks of carbon leakage, and to address distributional concerns, but must be balanced with efficacy and considerations of fairness. Coverage can be limited by determining which greenhouse gasses will be traded, setting emission thresholds or farm size thresholds, choosing the emissions sources covered (for instance beef, cereals, etc.), developing proxies for emission estimation (such as the livestock factors now incorporated into the UK inventory), or a combination of the above.

However, these choices may require politically sensitive decisions and need to be carefully calibrated: for example, the choice of size threshold may lead to perceptions of unfairness by actors immediately above and below the threshold. It may also lead to "gaming" by dividing properties to fall under a particular threshold. Certain activities may have higher mitigation potential, so focusing on them could make sense in terms of cost-benefit analysis. They may also have differing degrees of exposure to international trade, and therefore differing risks of carbon leakage. However, focusing on less-exposed sectors could lead to "internal leakage" as producers switch to non-regulated activities. Scattered or partial coverage could also distort the price signal across emission sources, lessening the policy's effectiveness.

Coverage could be designed using proxies such as feed purchases, activities such as tillage or manure management techniques, measurements such as soil tests, or outputs such as production. This can reduce the cost of implementation, but is less accurate in targeting the real source of emissions, and in incentivising the most cost-effective abatement choices, and would require a higher price to be effective, with potentially negative distributional effects[29].

An ETS instrument must also determine the degree of grandfathering or benchmarking for the allocation of free permits. Grandfathering means that producers are allocated free permits based on historical emissions. Under benchmarking they are allocated free permits based on their production and emissions benchmarks based on best practices. Grandfathering tends to be beneficial for more GHG intensive industries and can lead to windfall profits, but has often been used in the early phases of ETS systems to secure greater political acceptance from these actors. In the agriculture sector, the challenge of identifying emissions, particularly historical emissions, may mean that any approach to grandfathering would need to be based on levels of production activity, rather than emissions.

5.3 Tax instruments

A relatively straightforward way of ensuring that a carbon price is applied to some inputs to the agriculture sector would be through taxation of those inputs (although noting the political economy challenge that, in a sector with generally low profitability, this could lead to calls for increases in subsidies). Simple options for taxation include ending the current tax subsidy for agricultural diesel supplies (red diesel); or taxes on fertiliser inputs (although the carbon cost of artificial fertiliser production is already reflected in the ETS carbon price, a tax could indirectly address the emissions from fertiliser application). A fertiliser tax could also include more targeted incentives: one of the most effective options for NO_2 reduction is to add nitrification inhibitors to agricultural fertilisers (Martineau

[28] Karpas, Eric and Kerr, Suzi, (June 2011), Preliminary Evidence on Responses to the New Zealand Forestry Emissions Trading Scheme, Motu Working Paper 11-09. https://ssrn.com/abstract=1861866 or http://dx.doi.org/10.2139/ssrn.1861866

[29] Grosjean et al, 2018.

et al 2016). These are available but at a price premium, so farmers are unlikely to use these voluntarily. A regulatory requirement would be impossible to enforce but a differential tax regime might be a more effective option.

More challenging or politically controversial taxation options could include an emissions-linked tax on ruminant livestock. A tax on livestock numbers, rather than on livestock products, would provide incentives for production efficiency (for example, measures to improve animal health thereby reducing the level of "wasted" emissions from animals which do not meet slaughter weight, or are slow to meet slaughter weight); and could be differentiated in line with the information on diet, breed and age profile used for the new more accurate emissions inventory.

Tax subsidies (in addition to reduced rates as an incentive under the options identified above) can be treated as being effectively equivalent to grant mechanisms, or credit mechanisms. In this context, it should be noted that tax subsidies for afforestation existed in the UK until 1988, allowing high earners to offset the costs of afforestation against tax. Uptake was mostly by people unconnected with the AFOLU sectors, who employed forest companies to buy up rough grazing land, mostly in Scotland, and establish fast growing non-native conifer plantations. The policy was finally discredited following serious concerns about environmental damage that would be caused by draining and afforesting internationally important peatlands and wetlands in the Flow Country of northern Scotland. It should therefore be borne in mind as an example of the sort of risks associated with a poorly designed market-based instrument to encourage afforestation (see the discussion above of the risks associated with credit mechanisms).

5.4 Public support for agri-environment measures, afforestation, and other mitigation options

Current public support for all the AFOLU options discussed above is funded under the EU Common Agricultural Policy, as implemented by the four devolved governments. This ranges from requirements attached to farmers' income support payments (e.g. cross-compliance on soils, greening requirements for grass buffer strips on arable land) to highly targeted RDP investment support and annual management payments under 5-year agri-environment-climate contracts for specific actions (see also 4.1.1). Until Brexit the farmers' income support payments are wholly funded by the CAP and RDP support is part funded. The proposed UK Agriculture Bill[30] offers much wider scope to focus on paying farmers and foresters for public goods, including 'enriching wildlife habitats, preventing flooding, improving the quality of air, soil and peat, and planting trees'[31], but the Government has made clear it wishes to phase out income support payments to farmers.

The dependence of farmers on agricultural income support differs hugely across regions and farming systems; Defra estimates that the proportion of farms in England where costs (including depreciation) exceed revenue would rise from 16% in 2016-17 to 42% in the absence of income support payments. The figure will be much higher in the other three parts of the UK, as a result of the large area of less favoured areas (LFA) farmland, where loss of direct payments is seen as an existential threat to these farm businesses. The implementation priorities for the legislation which emerges following Parliamentary consideration of the Bill (and the forthcoming Environment Bill) will clearly differ from country to country, not just in response to the dependence of some farming areas on public support, but also to environmental priorities including afforestation and peatland. The withdrawal of direct

[30] Which applies to England and allows Wales and N Ireland to develop similar measures, but does not apply to Scotland https://www.gov.uk/government/publications/the-future-for-food-farming-and-the-environment-policy-statement-2018

[31] https://www.gov.uk/government/publications/the-future-for-food-farming-and-the-environment-policy-statement-2018/health-and-harmony-the-future-for-food-farming-and-the-environment-in-a-green-brexit-policy-statement

payments may also affect the policy reach of future public goods payments, with uptake greatest among the least profitable farms. This may put at risk some important measures, e.g. soil carbon protection in the arable sector, if these are offered as location specific agri-environment contracts, which highly profitable farms can choose to ignore. Legislation on protecting soil carbon in arable and grassland soils would be difficult to design and enforce (mainly because of soil organic matter metrics), which may leave standards and codes of practice (c.f. the UK forest Standard) and enhanced advisory services as the main public support alternatives. Note the potential for different approaches in devolved administrations, which have different priorities (carbon in Wales, afforestation in Scotland).

5.5 Consumption measures

While agriculture and rural development policies (alongside others) can greatly influence production in the agriculture and food and drinks sector, influencing consumption is another powerful lever through which to incentivise mitigation action in the agriculture sector. Consumption measures have repercussions not only on primary production but also on other supply chain actors. The following potential measures have been explored:

- **Introducing a carbon tax on food and drinks products** would incentivise low-carbon production methods, encourage a shift to consumption of less emissions-intensive foods, and ultimately reduce the (indirect) climate impact of food. The incidence of such a tax would have to be carefully designed, however. Applying the tax to purchases by the food and drink sector, rather than to sales from agriculture, would mean that manufacturers faced the tax regardless of the point of origin of the agricultural produce they use in manufacturing. This would reduce the risk of carbon leakage in the supply chain; but would also reduce the potential to create direct incentives towards lower-carbon production methods. A carbon tax would result in an increase in the costs of the food and drink products, with a disproportionate impact on poorer consumers. It may need to be balanced by reductions in tax rates or changes to benefits payments in order to address the regressive nature of the impact.
- **Charge on household waste**: Charges for residual household waste have the potential to reduce food waste, with positive repercussions through avoided emissions from agricultural products that are not consumed. However, organic food waste is likely to be a relatively small proportion of household waste, so the effectiveness of this measure in terms of mitigating emissions in agriculture could be quite low.
- **Extended producer responsibility for food waste in the food and drink sector.** Applying extended producer responsibility to food and drink producers would aim at internalising some of the negative climate impacts associated with the oversupply of food and ultimately food waste, and at incentivising packaging and marketing decisions which are consistent with reducing waste. Actions which could be taken by the sector in this respect might include:
    - Measures to discourage over-purchasing by consumers – e.g. removing multipack promotions and misleading advertising;
    - Providing clearer messages to consumers on the storage, preparation and consumption of products – e.g. greater clarity on date labelling; better communication on what 'best before' dates mean;
    - Optimising packaging to extend shelf-life on high value (and high climate impact) products – e.g. dairy and meat products;
    - Utilise edible products close to their 'use by' dates to generate value added for example in restaurants, or donate products to food banks.

6 Summary of options; and possible combinations

Policy option	Strength of incentive signal	Feasibility	Impact on other sectoral policies
Tradeable credits	High, but with a risk of poor targeting, and unwanted secondary impacts, e.g. on biodiversity.	Medium: mechanisms to address risks of poor targeting would add to complexity	Need for caps and other targets to be tightened to reflect the fact that they are being used as a proxy driver for AFOLU mitigation
Emissions trading	High in principle; although measures to tackle feasibility (e.g. reduced coverage) may reduce effectiveness	Low: monitoring, reporting and verification challenges are a barrier	Low
Public expenditure support: farming	Potentially high, depending on level of support available	High; although better targeting would raise administration costs both for administrators and beneficiaries	Would depend on tax receipts from other sectors.
Public expenditure support: forestry	Potentially significant, but risk of deadweight cost	High	Potential greater availability of harvested wood, either as fuel or as a material substitute.
Production taxes	Depends on level of tax. Design would need to address risks of carbon leakage.	Challenging; and risks of leakage	Low
Consumption taxes	Depends on level of tax, and sectoral coverage. Indirect impact on UK emissions.	Relatively straightforward, but with significant political risk	Potential impacts on retail and food processing sectors.
Voluntary measures	Negligible	Highly feasible to establish a system, although making it effective is more challenging.	None (other than the need for higher mitigation action elsewhere to compensate for a likely lack of progress in AFOLU sectors)
Regulation	Depends on scope and strength of regulation, but could eradicate some polluting actions at relatively low cost	Relatively straightforward; but becoming more complex as mitigation ambition increases	Low

We summarise above the main characteristics of each of the options, including the implications for other sectors. The nature of the AFOLU sectors, as discussed in this report, makes it challenging to include it in an economy-wide approach to carbon pricing. However, allowing this problem to lead to an approach where relatively inexpensive mitigation options in the AFOLU sectors are foregone, with more expensive mitigation required elsewhere, would clearly not be consistent with an economy-wide cost-effective decarbonisation strategy; and the need to develop experience with negative emissions technology, and identify those which can work at scale, means that there are strong arguments for a mitigation policy focus on the sector.

We share the Committee on Climate Change's view[32] that the current **voluntary** approach has failed to deliver its targets, and that a stronger framework (or, given the devolved nature of policymaking, frameworks) is needed. A key supporting element for such a framework should be further Government and research community work to identify the abatement opportunities which are most promising in terms of the volume and cost-effectiveness of emissions reductions, and to set indicative targets for progress in each of the parts of the UK.

In terms of the mechanisms on which the stronger framework would rely in order to drive progress, these could develop over time. Our assessment is that the targeting problems and risk of perverse incentives associated with a market-based system of **tradeable credits** makes this an unattractive option at present; and that the administrative challenges associated with a **"cap and trade" emissions trading mechanism** in the agriculture sector make this a non-starter. Some of the challenges with trading mechanisms may become more tractable as experience with and data from the monitoring associated with public expenditure options (see below) builds up over time. **Production taxes** appear to run significant risks of carbon leakage, and are not currently recommended (although, in due course, they could be introduced alongside tax measures on consumption).

A combination of **public expenditure** options, as part of the UK implementation of new agricultural policies after leaving the EU (and the Common Agricultural Policy), and a clearer **regulatory baseline**, looks the most promising approach. The regulatory baseline could mandate improved slurry and manure management, for example. The public expenditure mechanisms should be based on a clear set of targets for the abatement expected to be delivered respectively in the agriculture and forestry sectors at regional level, and monitoring against those targets. There may, over time, be scope for tendering mechanisms to be incorporated in public expenditure options, with farms or groups of farms, or forest managers, bidding to implement more abatement options, or plant more trees, in order to secure more of the available budget.

While the political feasibility of consumption-based measures such as taxes is judged to be currently low, we would recommend that the UK greenhouse gas footprint of its food consumption is monitored, and consideration given to setting indicative targets. Given that changes in food consumption patterns are likely to be an important component in delivering net zero carbon emissions by 2050, a broader policy debate on the subject needs to be generated – while recognising the cultural and social sensitivity of the subject. **Consumption taxes** on meat and dairy products could, over a longer time horizon, be introduced in order to deliver a combination of health and climate benefits.

A degree of connection between the AFOLU sectors and the rest of the economy could be introduced alongside the public expenditure options identified above. One approach, once a clear understanding had been developed of the £/tonne abatement being delivered through public expenditure, would be for regulated entities in other sectors to choose to add a contribution to the total agriculture budget, and receive credit for the imputed abatement. Thus, if abatement in agriculture and forestry were cheaper than marginal abatement in other sectors, expenditure could be increased without an increase in Government funding. Similarly, the proceeds of a future meat and dairy consumption tax

[32] "Reducing UK emissions: 2018 Progress report to Parliament", Committee on Climate Change, 2018

could be hypothecated to agriculture and forestry abatement. There are, however, political economy challenges to ensuring that mechanisms of this kind operate effectively and transparently; in particular, Treasury decisions on the amount of funding to allocate to the sector would be likely to reflect awareness of any transfers from other sectors (and, naturally), any hypothecation of tax revenues; and the baseline level of public expenditure would therefore be reduced.