Managing Land for **carbon**

A guide for farmers, land managers and advisers

Lake District National Park
University of Cumbria
Knowledge Transfer Partnerships
Technology Strategy Board
Driving Innovation

What's in it for me?

There are three reasons to manage land for carbon:

1 Reduce the impacts of climate change

Most scientists agree that the expected increase in global temperature must be minimised, if the changes in climate are to remain manageable. We've seen more examples of extreme weather in recent years and we're all aware of how that impacts on us as individuals, and as businesses which depend on the land.

2 Money available to fund changes in land management

Businesses are helping to fund projects which have climate change benefits, and there are some examples around Cumbria.

Funding is available now for woodland creation.
And this is on top of any other grant you might also receive.

Over the next few years, it is expected that funding will also be available for peatland restoration and woodland management. The price of carbon is predicted to rise to about £100 per tonne, and in the long-term other land management may also be eligible. Action can also be funded through existing grant schemes such as Forestry Commission grants for woodland management, or various types of land management through Environmental Stewardship from Natural England.

For more information on funding woodland creation from its carbon benefits, visit the Woodland Carbon Code website: **www.forestry.gov.uk/carboncode**

3 Avoid additional regulation

Agriculture was responsible for nine per cent of UK emissions in 2011. As other areas reduce their emissions, such as energy suppliers, the portion of greenhouse gases which agriculture is responsible for will go up.

The government have asked the agricultural industry to lead a voluntary approach on reducing their emissions, which will be reviewed again in 2016. To keep control of how emission savings are made, and ensure they remain voluntary – agriculture needs to be seen to be making improvements.

There is more carbon stored in global soils and vegetation than in the atmosphere.

Land management can maintain and enhance carbon storage to help combat climate change.

Jargon buster

Greenhouse gases (GHGs)
Gases in the atmosphere which cause global warming. They include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). CO_2 is the main greenhouse gas, but CH_4 and N_2O are the key emissions from the agricultural sector. For example from digestion of food by livestock, manure management, use of nitrogen fertilisers and soil cultivation. CO_2 is absorbed or sequestered by vegetation during growth and stored in its biomass as carbon until decay.

CO_2e
Shorthand for carbon dioxide equivalent. This is a way of expressing the impact of all the different greenhouse gases as a single number. One molecule of CH_4 or N_2O has a greater warming effect than one molecule of CO_2.

Climate change mitigation
Efforts to reduce or prevent greenhouse gas emissions or to remove carbon dioxide from the atmosphere.

Carbon sequestration
The removal of carbon dioxide from the atmosphere and storage in another system, such as vegetation. If the carbon dioxide sequestered is more than the carbon dioxide emitted, the store is increasing and is known as a **carbon sink.**

Carbon flux
Occurs when carbon moves between two systems such as plant material and the atmosphere. Depending on which way the carbon is moving, this would also be called sequestration (from the atmosphere) or emissions (to the atmosphere). If a system is emitting more carbon to the atmosphere than it is sequestering, it is known as a **carbon source.**

Carbon finance
Money made available for storing or sequestering carbon.

Carbon trading
A market mechanism to tackle greenhouse gas emissions. Instead of cutting their own emissions to meet mandatory targets, companies can pay someone else to cut theirs, or to sequester carbon.

Carbon footprint
The quantity of greenhouse gases that enter the atmosphere because of the activities of a person or business. Where these emissions have been minimised, this is referred to as low carbon or carbon lean.

Carbon neutral
A person, business or activity that achieves zero carbon emissions, by balancing the CO_2 they emit through sequestering or buying an equivalent amount of carbon from elsewhere.

Biomass
Biological material derived from living or recently living organisms. In the context of carbon management, this is usually plant-based material.

Soil carbon
Largely refers to soil organic carbon (SOC) and is the carbon stored within organic matter in the soil. This comes from decomposing plant material and is fundamental for soil health. Over 50 per cent of soil organic matter is pure carbon.

Carbon or CO_2 ?
Plants and soil store carbon, but it is carbon dioxide (CO_2) which is found in the atmosphere and contributes to climate change. One tonne of carbon is equal to 3.67 tonnes of CO_2. So if you have 10 tonnes of carbon stored, that's equivalent to 36.7 tonnes of CO_2 emissions.

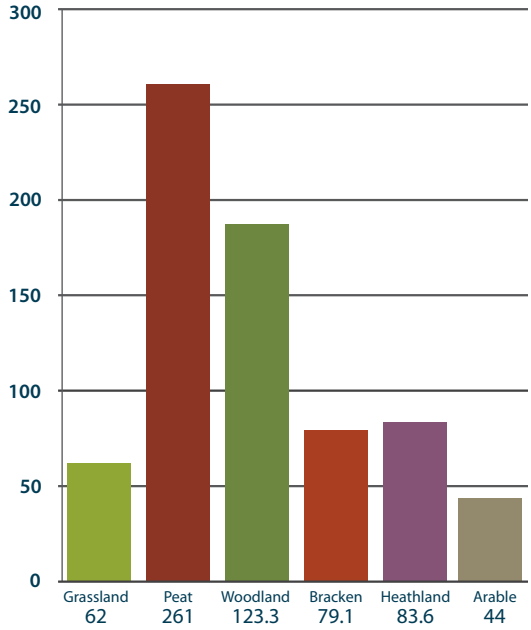
This booklet aims to help land managers be as carbon-efficient as possible within the boundaries of their own farming system.

Developed in the Lake District National Park (LDNP), it summarises information on carbon in a range of habitats, and suggests management practices to favour and those to avoid. For each habitat, it provides a table for you to complete to help you estimate how much carbon is stored in the soil and vegetation on your farm.

Thinking about managing land for carbon across the whole farm will help you determine which options best suit your farming system and provide the most carbon benefits. While some areas of the farm will be used more intensively, you can still improve your carbon footprint by managing some areas really well for carbon and making small alterations across the farm wherever they are possible. Some alterations increase productivity too.

Contents

How much carbon is stored in different habitats



Estimated figures of carbon stored in soil and vegetation in tonnes of carbon per hectare

For a full list of references, visit the website: **www.lakedistrict.gov.uk/carbon**

Introduction

The climate is changing. Extreme weather events like floods and droughts are happening more often, and the world's average temperature is rising.

However, we can take action to slow climate change by reducing net emissions of greenhouse gases. This booklet looks at some of the ways that land managers and farmers in the Lake District National Park can play their part. It focuses on carbon dioxide, the most common greenhouse gas, and discusses land management practices that can help to increase carbon storage in different habitats.

In the LDNP, total GHG emissions from residents and visitors are estimated at 2.3 million tonnes of CO_2e per year.

In comparison, 84 million tonnes of CO_2e are stored in the Park's peat soils and 12.6 million tonnes of CO_2e in its woodland.

Why is carbon important?

GHGs are naturally present in the Earth's atmosphere, and they are essential to maintaining the temperature of the planet. But when too many of them are released into the atmosphere as a result of human action, this interferes with the planet's natural heating and cooling processes.

CO_2 is normally regulated by natural processes which absorb carbon, storing it in soils and vegetation. So supporting these processes by balancing emissions and absorption is a vital part of keeping climate change under control.

Where is carbon found?

Carbon is a major component of plants and soils. Globally, more carbon is stored in soils and vegetation than in the atmosphere.

Soil generally stores more carbon than vegetation. Every type of soil has the capacity to store carbon, but some types store more than others. Capacity also depends on the type of vegetation the soil supports. Plant matter is the most important source of carbon inputs to soil.

- The uplands – including the LDNP – contain more than 40 per cent of soil carbon in England.
- Peat soils are the largest store of land-based carbon in the UK – storing more carbon than the forests of Britain and France combined.
- Productive woodland has the greatest potential to sequester carbon from the atmosphere. This is because peak CO_2 uptake occurs at the same time as peak timber growth.

How does land management affect carbon?

Land management directly influences the way that carbon moves around ecosystems and the atmosphere. This can have either a positive or negative impact on climate change.

For example, the UK Land Use, Land Use Change and Forestry sector removed 3.8 million tonnes of CO_2 from the atmosphere in 2010. However, carbon-rich peat soils in the Lake District alone are estimated to be releasing 32,000 tonnes of CO_2e each year as a result of being in poor condition.

While emissions from Lake District peatlands are a small proportion of the overall peatland store, an immediate carbon saving could be made by altering land management. This is roughly equivalent to the emissions from all non-food shopping products bought by Lake District residents over a year.

What can land managers do to protect and sequester carbon?

Looking after soils and maximising vegetation growth are the general principles of managing land for carbon.

Land management has multiple objectives and has to take into account many different factors. Managing land to protect carbon and reduce GHG emissions should not be at the total expense of the other ecosystem services it provides, such as food production and water quality. But some management practices which support carbon sequestration can be win-win strategies, for example enhancing productivity and mitigating climate change at the same time. In other cases, decisions about trade-offs between different strategies need to be made on a farm-by-farm basis.

This booklet provides advice on how land managers can protect and sequester carbon, and suggests management practices to favour and avoid. These can be applied to your own site, allowing you to make decisions based on what is best for your farm and your farming system. Where changes require permission, contact the relevant authority: for example Natural England, the Forestry Commission or the Environment Agency.

Linking carbon landscapes and agricultural emissions

Agriculture is responsible for nine per cent of UK GHG emissions (2011 figures). However, as other sectors reduce their emissions, the agricultural slice will become much larger. Therefore agriculture has to be seen to be taking action too. The government target is for agriculture to reduce emissions in England by three million tonnes of CO_2e by 2020.

The government has asked the agricultural industry to lead a voluntary approach on reducing their emissions, which was reviewed in 2012. To avoid a regulatory approach in future or 'carbon tax', progress will need to continue.

The agricultural industry has created a greenhouse gas action plan which focuses on production efficiencies to reduce GHG emissions. This means there are often financial benefits too. For livestock, activity concentrates on things such as animal health; increasing the number of young per adult animal, and feed and nutrition improvements, leading to faster fattening times and reduced emissions resulting from digestion.

Soil and land management is also a priority area, but the detail in the action plan on how to enhance carbon sequestration and storage is limited. This booklet helps to plug that gap and provides information on how to use the carbon resource around us to help mitigate climate change.

Depending on how it is recorded nationally, some land management fits the government target for an 80 per cent reduction in UK GHG emissions by 2050 more easily than others. But any action that reduces GHGs in the atmosphere helps mitigate climate change.

Calculating carbon footprints

Your farm's carbon footprint is the total amount of greenhouse gas emissions your farm is responsible for.

This is calculated from the emissions from different aspects of the farm business, including manure storage and management; fertiliser use, livestock feed and digestion and land use change. Some also include land management, sequestration and participation in agri-environment schemes. A range of carbon footprinting tools are available.

The CALM Calculator is a free tool for calculating the carbon footprint of your **whole farm.** It stores your results so you can come back to see how your footprint has changed. You can access it at: **www.calm.cla.org.uk .**

The English Beef and Lamb Executive has developed 'What-if' tools to calculate the carbon footprint per kilogram of **product.** These free tools let you alter your inputs to see which actions increase or decrease the carbon footprint of your product. The tool for sheep farmers is currently the only one available, but others are expected. You can access it at: **www.eblex.org.uk/returns/sheep-carbon-footprint.aspx .**

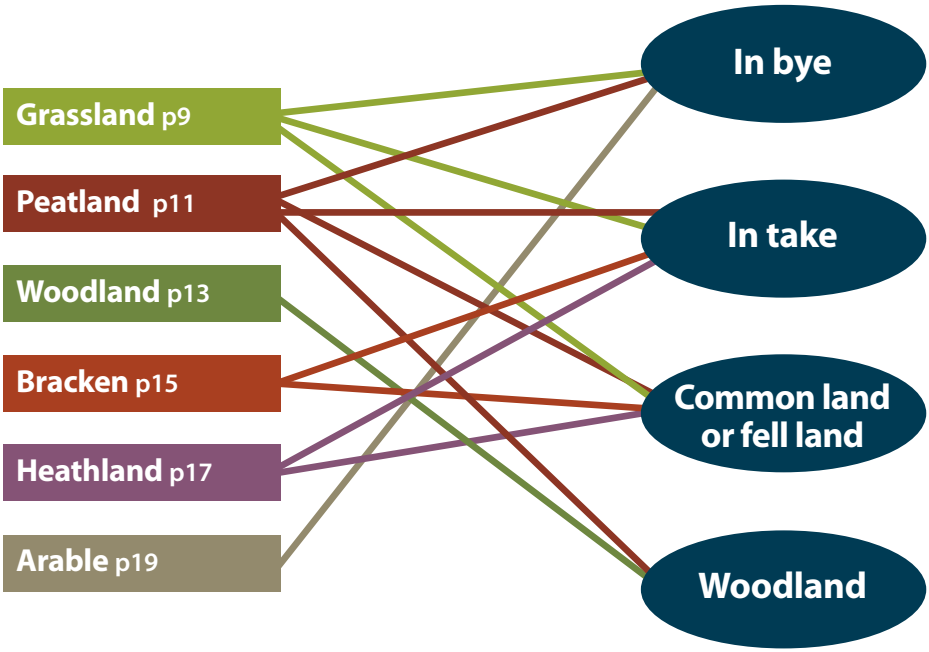
Limitations

The information provided here and throughout this booklet is based on the best current data available (summer 2013). For some habitats only a small quantity of data is available. Direct comparisons between habitats are not necessarily comparing like with like because different sources of information have been used.

General principles of managing land for carbon are looking after soils and maximising vegetation growth.

Semi-natural vegetation tends to store more carbon in the plants and soil than improved grassland, whereas arable land is the most depleted carbon store.

Where can different habitats be found on the farm?



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Although the soil beneath grassland usually stores less carbon than most other habitats, its wide coverage means that it holds almost a third of the UK's below-ground carbon stock. In 2010, UK grassland sequestered 4.7 million tonnes of CO_2.

As well as soil carbon, the carbon in grassland vegetation is also important, making up about six per cent of the UK's vegetation carbon stock.

Grassland

Estimates suggest grassland sequesters 0.24 tonnes of carbon per hectare per year. Across 50 hectares of grassland that's an annual carbon capture of 44 tonnes of CO_2e.

Balancing food production and carbon storage

Whilst other habitats may store or sequester more carbon, grassland is a major part of any livestock farm and clearly vital for food production. Increasing soil organic matter; reducing soil erosion; planting in-field trees or taking field margins out of management can all enhance the carbon benefits from grassland.

Adopting practices that minimise emissions, protect existing carbon storage in the soil and maximise sequestration are key to balancing food production and carbon storage. These decisions will need to be made on a farm by farm basis, depending on what changes may be possible.

Different types of grassland

The broad category of grassland is made up of several different habitats, and each will store a slightly different amount of carbon. Soil type will also affect the amount of carbon stored.

Acid grassland can indicate high-carbon soils which have degraded through the loss of organic content. Also, acid grasslands have slower decomposition rates for organic material, which is partly why the carbon storage is higher in these grasslands.

Type of Grassland	Carbon storage tonnes per hectare
Improved grassland Higher productivity, fewer grass species and maintained by inputs of fertiliser and weed control	**62.0**
Neutral grassland pH between 4.5 and 6.5, more species than improved grassland	**63.4**
Acid grassland pH below 5.5	**83.3**

Soil type and grassland management practices affect the carbon balance

Soil types and grassland management practices are inter-related and influence the balance between carbon storage and emissions.

The production and application of lime, mineral fertilisers and livestock manure are sources of GHG emissions. Efficient use of fertiliser and lime inputs reduces GHG emissions both from the soil and in their manufacture. Having sufficient slurry storage enables more strategic application.

Management practices that influence soil structure also influence carbon storage capacity.

Having enough winter housing can help remove pressure from water-logged pasture, reducing soil erosion and compaction. Increased plant root mass, rate of plant growth and root depth deliver carbon benefits, whereas soil erosion and compaction will reduce the carbon benefits and the health of the soil – which also affects productivity.

How much carbon is stored in the grassland on your farm?

	UK average values, tonnes of carbon stored per hectare, current best estimates			Your farm	
Habitat	Carbon stored in top 0 - 15cm of soil	Carbon stored in vegetation	Total carbon stored	Area of grassland in hectares	Estimated carbon store in tonnes
Grassland	61	1	62		

1. Enter the number of hectares of grassland on your farm in the yellow box.
2. Multiply your answer by the figure in the blue box.
3. Enter the answer in the green box (so blue x yellow = green).
4. To calculate the carbon storage across your whole farm, add your answer to the grassland row of the green column in the table on the back page.

Good practices in managing grassland for carbon

- Improve species diversity of grassland through species management, and include nitrogen-fixing legumes.
- Avoid overstocking, which can lead to excessive removal of biomass and surface vegetation, increased risk of topsoil compaction, and soil erosion.
- Efficient use of lime and other surface treatments should be closely monitored using soil tests
- Increase managed return of farm waste to the soil.
- Improve soil structure.
- Take field corners and margins out of production, and retain and protect existing areas of in-field trees.
- Retain permanent pasture where possible.
- Increase the length of ley for non-permanent pasture.

Practices to avoid where possible

- Ploughing and re-seeding.
- Allowing soil erosion and rut creation.
- Allowing soil compaction, especially on clay or silt soils, where it is irreversible.

On organic (peaty) soils:

- Applying lime or fertiliser.
- Drainage.

Peat soils cover 40 per cent of the LDNP, and there are estimated to be between 17,000 and 18,000 km^2 of deep peat soils in the UK. A huge amount of carbon is stored in UK peat soils, estimated between three and 16 billion tonnes.

Peatlands have the potential for ongoing accumulation of carbon. But only one per cent of England's deep peat soils remain waterlogged, undamaged and actively continue to form peat.

Peatland

Different peatland habitats

Peat has a relatively high content of organic matter compared to other soils, making it a very important store of carbon. This high organic matter content is the result of combined plant growth and waterlogging, which means that not all dead plant matter breaks down, but instead stays in the soil. The waterlogged mass of partly decomposed plant material creates the thick black or brown soil commonly called peat.

Peat can be shallow or deep, or found in pockets in other soil types. It is found under various habitats including bogs, mires, fens, heaths and acid grassland. Sphagnum is found in healthy bogs and has a particularly important role in sequestering carbon.

Peatland: carbon sink or source of emissions?

Peat is a particularly complex ecosystem to manage for carbon. While undamaged peat soils sequester carbon, peatlands can also emit significant quantities of CO_2. This happens when peatland ecosystems are damaged. Draining, liming, over-grazing and fertiliser addition can all contribute to turning peat soils from a carbon sink to a source of emissions.

While 84 million tonnes of CO_2e are estimated to be stored in the peat soils of the LDNP, it is also estimated that they are emitting 32,000 tonnes of CO_2 each year.

Restoring degraded peatlands can combat emissions and sequester additional carbon, but can also be very costly. A far more cost-effective approach is to maintain sites that are already in a good condition.


Bog vegetation


Sphagnum

How much carbon is stored in the peat bogs on my farm?

	UK average values, tonnes of carbon stored per hectare, current best estimates			Your farm	
Habitat	Carbon stored in top 0 - 50cm of soil	Carbon stored in vegetation	Total carbon stored	Area of bog in hectares	Estimated carbon store in tonnes
Peat soils under bog habitat	259	2	261		

1. Enter the number of hectares of peat bog on your farm in the yellow box.
2. Multiply your answer by the figure in the blue box.
3. Enter the answer in the green box (so blue x yellow = green).
4. To calculate carbon storage across your whole farm, add your answer to the peatbog row of the green column in the table on the back page.

If you know you have a lot of peaty soil on your farm, then this calculation is likely to be an underestimate of the carbon content. The total carbon stored by peat soils on the farm is difficult to quantify without a site-specific survey.

Good practices in managing peatland for carbon

- Halt or reduce drainage, and consider gully or 'grip' blocking.
- Reduce liming.
- Reduce fertiliser use, but where it is necessary use solid manure rather than mineral fertilisers or slurry, and apply during a vegetation growth phase.
- Ensure that grazing is at a sustainable level, and that stocking levels are appropriate and take into account wild animals like deer.
- Reduce grazing on very wet sites and during wet periods of the year.
- If using burning as a management practice, control it to ensure that only above-ground vegetation is burned and that root mats remain untouched.
- Consider peat restoration including re-vegetating bare peat soils and re-wetting, but seek site-specific specialist advice.

Practices to avoid where possible

- Drainage.
- Ploughing.
- Disturbing soil.
- Applying lime, fertiliser or manure
- Overgrazing.

Woodland covers nearly three million hectares in the UK, comprising 12 per cent of total area. There are estimated to be 28,442 hectares of woodland in the LDNP, almost equally balanced between conifer and broadleaf species.

Of all the habitats, woodland stores the most carbon in its vegetation – in the woody biomass of the trees themselves. Woodlands contribute 80 per cent of the vegetation carbon stock in the UK. In the LDNP around 12.6 million tonnes of carbon are stored in tree biomass. But 75 per cent of the carbon stored in woodlands is found in the soil.

Woodlands also sequester carbon. Existing woodlands reduce GHG emissions in the LDNP by an estimated 164,750 tonnes of CO_2 each year. This is more than three times the emissions resulting from flights taken by all the residents of the Lake District.

Which woodlands store most carbon, and when?

Carbon storage depends on the species in a woodland, the age of individual trees, the type and quality of soil, and management practices such as the spacing of trees.

Carbon sequestration is greatest when trees are growing vigorously. This means woodlands with a larger proportion of fully-mature trees will sequester less carbon, but are a much larger store of existing carbon. So different types of woodland management have different carbon benefits.

Managed woodlands also provide timber and wood-fuel. Carbon is stored in the harvested timber and new trees growing where the wood was harvested continue to sequester carbon. Also wood-fuel can be used to substitute fossil fuel use, and timber to substitute carbon-intensive products such as concrete or steel.

Woodland

How much carbon is stored in the woodland on your farm?

	UK average values, tonnes of carbon stored per hectare, current best estimates			Your farm	
Habitat	Carbon stored in top 0 -15cm of soil	Carbon stored in vegetation	Total carbon stored	Area of woodland in hectares	Estimated carbon store in tonnes
Woodland	66.3	57.0	123.3		

1. Enter the number of hectares of woodland on your farm in the yellow box.
2. Multiply your answer by the figure in the blue box.
3. Enter the answer in the green box (so blue x yellow = green).
4. To calculate carbon storage across your whole farm, add your answer to the woodland row of the green column in the table on the back page.

The diversity of woodland species and management practices mean that this calculation will only provide you with a very general estimate. To undertake a site-specific carbon storage survey for your woodland, please refer to the Woodland Carbon Code (see page 1) for methods and guidance.

Good practices in managing woodland for carbon

- Protect soils during forestry operations.
- Thin, harvest and re-stock trees to maximise sequestration provided by younger stands and provide additional carbon storage in harvested timber and substitution of fossil fuels with wood-fuel.
- Practise continuous cover forestry.
- Deer management.
- Select species carefully when planting and choose mixtures of species to minimise the risk of damage from pests and diseases.
- Protect trees from livestock and wild animals using tree shelters and fencing.
- Favour natural regeneration over planting where possible.

Practices to avoid where possible

- Allowing grazing amongst seedlings and saplings.
- Clear-felling large areas.

Bracken thrives in upland areas. While it covers only one per cent of the UK, it accounts for at least four per cent of the LDNP. Bracken is an indicator of deep and fertile soils, which store over 750,000 tonnes of carbon in the LDNP.

Bracken

Dilemmas in bracken management

Although it stores carbon relatively well, bracken is also a vigorous species that smothers other habitats. It has little value in its own right, although it supports some bird and butterfly species with high conservation value. It harbours sheep ticks which spread disease, and its fronds contain toxins and carcinogens. The challenge in bracken management is how best to control the habitat.

Bracken habitat is an early stage in the natural transition to woodland. Eradicating bracken with the aim of reversal to the previous habitat is difficult and often unsuccessful.

But accelerating the transition to woodland can be cost-effective and encourages carbon storage.

How much carbon is stored in the bracken habitat on your farm?

	UK average values, tonnes of carbon stored per hectare, current best estimates			Your farm	
Habitat	Carbon stored in top 0 - 15cm of soil	Carbon stored in vegetation	Total carbon stored	Area of bracken in hectares	Estimated carbon store in tonnes
Bracken	77.1	2	79.1		

1. Enter the number of hectares of bracken on your farm in the yellow box.
2. Multiply your answer by the figure in the blue box.
3. Enter the answer in the green box (so blue x yellow = green).
4. To calculate carbon storage across your whole farm, add your answer to the bracken row of the green column in the table on the back page.

There is very little data on carbon storage in bracken, and it should be noted that estimates will vary seasonally.

Good practices in managing bracken for carbon

- Convert to woodland.
- Avoid soil erosion.
- Consider the possibility of harvesting bracken to use as a biofuel, or composting it and applying it as a potassium-rich soil amendment.

Practices to avoid where possible

- Ploughing.
- Reverting to land uses that store less carbon.

Heathland is characterised by vegetation from the heather and gorse families, and covers 12 per cent of the LDNP. Dry heath usually occurs on well-drained, nutrient-poor acid soils, and wet heath on peaty soils. Carbon storage in heathlands on sandy soils will be comparatively smaller.

Heathland

Impact of heathland management on carbon

The openness of heathland habitats is the product of continuous, long-term management. Heathland sequesters carbon during the later growth and early-mature stages of the cycle whereas the bare ground stage is a source of emissions.

Fire is an integral part of many heathland management systems. In the short-term, burning releases CO_2 into the atmosphere. But carefully-managed cool fires can help prevent a deep hot burn where the carbon stored in the soil is also released.

Without management, most heathland will be invaded by bracken, scrub and trees (the exception is montane heath at high altitudes). This could potentially lead to increased carbon sequestration, but would lead to the disappearance of an important habitat. Heathland stores more carbon per hectare in soil and vegetation combined than grassland.

How much carbon is stored in the heathland on your farm?

	UK average values, tonnes of carbon stored per hectare, current best estimates			Your farm	
Habitat	Carbon stored in top 0 - 15cm of soil	Carbon stored in vegetation	Total carbon stored	Area of heathland in hectares	Estimated carbon store in tonnes
Heathland	81.6	2	83.6		

1. Enter the number of hectares of heathland on your farm in the yellow box.
2. Multiply your answer by the figure in the blue box.
3. Enter the answer in the green box (so blue x yellow = green).
4. To calculate carbon storage across your whole farm, add your answer to the heathland row of the green column in the table on the back page.

Good practices in managing heathland for carbon

- If using burning as a management practice, control it to ensure that only above-ground vegetation is burned and that root mats remain untouched.
- Consider management by grazing rather than burning, but avoid overgrazing.
- If restoring heathland from forestry, use a gradual felling cycle rather than clear-felling.

Practices to avoid where possible

- Disturbing soil through livestock trampling or vegetation loss.
- Drainage.

Arable and horticultural land

How much carbon is stored in the arable and horticultural land on my farm?

	UK average values, tonnes of carbon stored per hectare, current best estimates			Your farm	
Habitat	Carbon stored in top 0 - 15cm of soil	Carbon stored in vegetation	Total carbon stored	Area of arable and horticultural land in hectares	Estimated carbon store in tonnes
Arable and horticultural land	43	1	44		

1. Enter the number of hectares of arable and horticultural land on your farm in the yellow box.
2. Multiply your answer by the figure in the blue box.
3. Enter the answer in the green box (so blue x yellow = green).
4. To calculate the carbon storage across your whole farm, add your answer to the arable and horticultural row of the green column in the table on the back page.

Good practices in managing agricultural and horticultural land for carbon

- Apply minimum tillage depth and reduce tillage frequency.
- Plant deep-rooting and perennial crops to maximise biomass, and cover crops to avoid bare ground.
- Return farm waste and crop residues to the soil.
- Retain and protect existing trees in fields, hedgerows and tree-belts.
- Consider taking field margins and corners out of production.
- Consider incorporating a two-year grass–clover–grass ley into the crop rotation.
- Follow lines of field contours rather than slope gradients.
- Use erosion controlling buffer strips and riparian filters.

Practices to avoid where possible

- Allowing soil erosion or bare ground.

On organic (peaty) soils:

- Ploughing, tilling or drainage.
- Planting root crops which disturb the soil.

Arable land is clearly vital for food production. The main carbon losses from arable systems come from harvesting plant biomass and soil erosion. Adopting practices that minimise these losses are key to balancing food production and carbon storage.

Arable and horticultural land, which covers three per cent of the LDNP, stores less carbon per tonne of soil than any other habitat type. Nonetheless, the extensive area of arable land in the UK means that it is one of the largest stores of soil carbon in the country.

Arable land is usually a net emitter, meaning that the carbon it stores will be depleted over time.

Coast and saltmarsh

Coastal habitats store carbon at different rates depending on soil and vegetation type. Carbon sequestration rates are estimated to be high in saltmarsh and sand dunes because of sediment accumulation.

- Saltmarshes contribute less than one per cent of the UK's total soil carbon stock, and are estimated to store between 0.64 and 2.19 tonnes of carbon per hectare each year.
- Sand dunes on the west coast of the UK are estimated to store between 0.58 and 0.73 tonnes of carbon per hectare each year. Older sand dunes and those under shrubs or trees store more carbon than bare dunes.

In some places, conversion of arable land to saltmarsh may be possible, significantly increasing carbon storage. A fundamental aim of saltmarsh management for carbon is to reduce nutrient enrichment, particularly from river water polluted with nitrogen.

Individual trees

Existing trees, whether in fields, hedgerows or orchards, can be valuable carbon stores.

Managing them effectively can improve carbon storage with very little impact on agricultural production.

Good practices to maximise and protect carbon storage include

- Ensuring that the soil around in-field trees is not compacted by livestock.
- Minimising soil disturbance and compaction around orchard trees during harvest and management.
- Maintain single trees in hedgerows which have grown significantly above the height of the hedge. Ensure that replacement trees are allowed to establish as older specimens reach maturity.

Field margins and hedgerows

Field boundaries can be managed to maximise carbon benefits with minimal impact on agricultural production. Those which have the most vegetation store the most carbon. So tree belts are the most valuable in terms of carbon storage, followed by hedgerows and then grass strips.

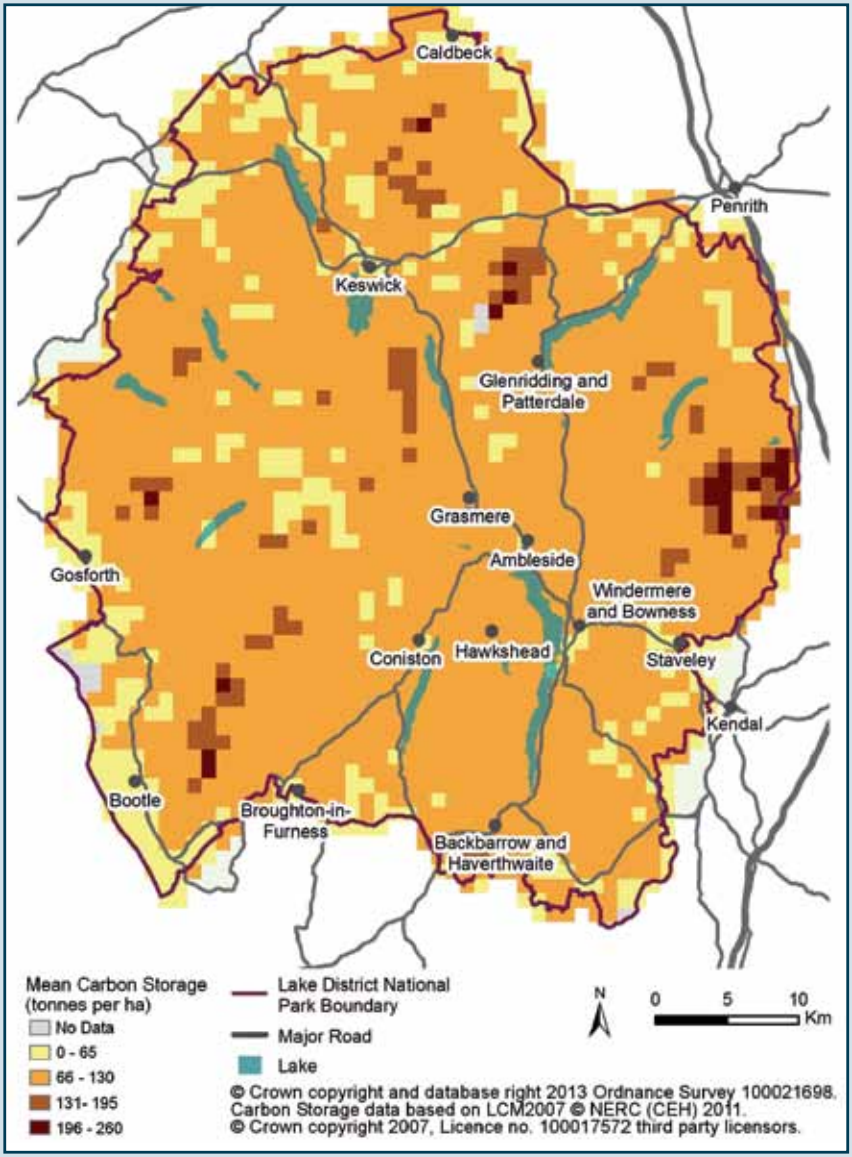
Field corners or margins which are allowed to grow up also favour carbon capture.

Hedgerows store up to as much as five tonnes of carbon per hectare of hedgerow.

Good practices to maximise carbon storage and sequestration include

- Allowing hedges to grow higher.
- Taking field margins or corners out of production, or widening existing field margins.
- Planting up hedgerow gaps.
- Avoiding soil disturbance.
- In hedgerows, maintain large trees which have grown significantly above the height of the hedge. Ensure when cutting that replacement trees have opportunity to establish.

Carbon storage in the Lake District National Park



The map shows estimated existing carbon storage in soil and vegetation within the Lake District National Park.

An interactive version of this map is available on the website at: **www.lakedistrict.gov.uk/carbon**

For a more detailed description of carbon storage on your farm, fill out the easy-to-use table on the back page of this booklet.

How much carbon is stored on your farm?

To find out the carbon storage for your whole farm:

1. Insert the answers you have already calculated for each habitat from within the booklet into the green column.
2. Add these together in the orange box, to get an overall estimate of tonnes of carbon stored on your farm. To compare with CO_2 emissions, multiply your answer by 3.67. This gives you carbon storage equivalent to tonnes of CO_2.

	Your farm
Habitat	Estimated carbon store in tonnes
Grassland	
Peat under bog habitat	
Woodland	
Heathland	
Bracken	
Arable and horticultural	
Estimated total carbon storage for your farm	

For further information about managing land for carbon, this project and for a full list of references, visit the website: **www.lakedistrict.gov.uk/carbon**

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