Grazing Livestock

It's not the cow but the how

Sustainable Food Trust

Acknowledgements

In memory of Richard Young, former SFT Policy Director.

Written and researched by Robert Barbour, Imogen Crossland, Susanna Smith, Lesley Mitchell and Richard Young.

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Foreword

I was delighted to have been asked to contribute a foreword for this timely report, which explores the role of grazing livestock in sustainable farming systems.

I have known the founder of the Sustainable Food Trust, Patrick Holden, for many years and worked with him closely during the run-up to the launch of the UK Register of Organic Standards, which I introduced in 1987 when UK Minister of Agriculture.

In my more recent role as Chairman of the UK Climate Change Committee, I have had to face up to the negative impacts of livestock on greenhouse gas emissions, including those from intensively managed poultry, pigs and cattle. However, what few seem to understand is that there is a need to differentiate between those livestock systems which are part of the problem in terms of net emissions, and those which, under the correct management, are potentially part of the solution.

I have a small mixed organic arable and livestock farm in Suffolk and this makes me appreciate the importance of the evidence that the researchers of this report have pulled together to provide the reader with accurate information about the differences between livestock systems – those which are contributing significantly to the climate, nature and public health crises we face, and those which are largely beneficial.

Regenerative and organic farms provide significant quantities of nutrient-dense meat and milk; produce nutritious crops without a reliance on agrochemicals; and create and maintain landscapes rich in biodiversity, carbon, and social value – these are all key benefits which require grazing livestock as part of a food system transformation.

Many people will question the climate impacts of such an approach. However, as the report shows, when we measure these impacts in a more holistic way – by properly accounting for different types of emissions; the sequestration of carbon; and a broader range of indicators relevant to the measurement of carbon footprints – grazing animals can be seen to play a key role in a food system that delivers benefits for the climate as well as the environment and human health.

In this connection, I believe this report could help to resolve some of the not inconsiderable public confusion about the impact on climate change of ruminant animals in general and cows in particular. This confusion has led to a widespread view that all cattle are unsustainable, but it doesn't have to be this way – providing we farm and eat differently.

My hope is that this report is widely read and that it will play a significant role in showing the difference between the farming systems that are practiced by regenerative and organic farmers, and those where intensive husbandry adds more to negative environmental and climate impacts.

Lord Deben
Former Chair,
Climate Change Committee

Preface

There has often been a failure to differentiate between livestock which are part of the problem and those which are part of the solution. This failure has had a profoundly distorting impact on the dialogue about our future food systems.

This report has the potential to make an important contribution to this debate. Without livestock, it will be difficult, if not impossible to transition to biologically based farming systems which operate within planetary boundaries, work in harmony with nature and still feed the world. There are many reasons for this, but perhaps the biggest is that really the only way to produce food from the fertility building phase of diverse crop rotations is through grazing animals.

Take my farm as an example. We are 51 years in, farming 300 acres in a sustainable fashion, as best we know how. We have used no chemical inputs for the entire half century. Our biodiversity and social outcomes are amazing, and we may even be carbon negative.

But can a farming system such as ours be productive? Without livestock, the answer is no. Around 90% of our land is grass at any one time and our food output reflects that: 30 tons of cheese, perhaps 100,000 litres of milk, a few tonnes of beef and this year around 10 tonnes of carrots, which are being sold as part of a local school food procurement initiative.

So, the majority of the food we produce comes from livestock. On half our land, the system depends upon a rotation with a long fertility building phase, mainly of grasses, clovers and herbs, while the other half is incapable of growing crops.

My farm is far from unique. Nearly two thirds of the UK's agricultural area is grassland, and an increasing number of arable farms are seeing major benefits from re-introducing livestock into their rotations. If we didn't have grazing livestock on the land, the capacity to feed people from sustainable production systems would be radically reduced.

The real problem we face is undoing decades of agricultural intensification and the harm this has caused. This includes factory-style livestock enterprises, which are umbilically dependent on cheap grain produced with chemical inputs. This will be a challenge, of course, but in an increasingly unstable world, our ability to feed ourselves in a more resilient and regenerative manner is only going to become more crucial.

I want to end this foreword by paying homage to my dear friend Richard Young (1950-2023), who was the driving force behind this report. His compassion for animals, attention to detail and general love for nature and humanity are all woven into the text of this report. I know that I speak for everyone involved in lamenting his loss and hoping that it makes a significant contribution to his legacy.

Patrick Holden
Founder and CEO,
Sustainable Food Trust

Executive Summary

A nationwide transition to farming systems based on regenerative, biological and circular principles would help address climate change, restore biodiversity and deliver a wide range of social benefits.

However, this transformation will be difficult, if not impossible to achieve, without the integration of grazing animals - in particular, sheep and cattle.

This is the key conclusion of this report, which explores the central role that grazing livestock could play in supporting a UK-wide transition to a more circular and resilient food system - provided we farm and eat differently.

PART 1: GRAZING LIVESTOCK AND THE DELIVERY OF PUBLIC GOODS

1. Regenerative mixed farming

Transitioning to a food system that does not rely on energy-intensive and environmentally damaging agrochemicals will require the widespread adoption of crop rotations which incorporate fertility-building grass and clover 'leys'. These temporary grasslands deliver multiple other benefits, including for soil health and on-farm biodiversity. Because the only way to produce human-edible food from grass is through grazing animals, these systems generally require the introduction of livestock, to maximise productivity and sustainability.

2. Carbon storage and sequestration

Biologically based farming systems also hold the potential to rebuild many of the carbon stocks lost due to decades of intensive farming – through the re-introduction of fertility-building leys into crop rotations, more regenerative grassland management and the integration of trees and livestock. Published estimates suggest that these practices, if applied together at scale, could sequester a very significant amount of carbon (equivalent to 60% or more of current UK livestock emissions) over the coming decades – with some pioneering farms even capturing as much or more than they emit. While further research is required, this could make a major contribution to reducing the food system's climate impact – whilst crucially, delivering a wide range of other farm and environmental benefits.

3. Protecting and restoring biodiversity

Moving to low-input, pasture-based grazing systems would help reverse the enormous loss of biodiversity that has occurred across our arable and improved grassland areas over the past century, by fostering a more diverse farmed landscape, and by reducing pollution from agrochemicals use and intensive livestock production. Grazing is also essential for the conservation of many of the UK's most important habitats and species, and can even play a central role in rewilding projects.

4. Nutrition and food security

Meat and milk from livestock fed primarily on grass could make a significant contribution to the UK's supply of protein, fats and several key micronutrients, some of which are more difficult to obtain from plant sources. Rearing animals largely on grass, rather than on grains that could otherwise be used for direct human consumption, would also help relieve the pressure upon our finite and increasingly stressed arable land area, bringing notable benefits for national food security.

5. Communities and landscapes

Grazing livestock play a central role in the social and cultural life of many rural communities, and help shape cherished grassland landscapes. A shift to lower input, pasture-based systems could build on this, in various ways: for instance, through increased opportunities for rural employment (including the creation of livestock-related jobs in arable areas), the fostering of more diverse landscapes, and improved mental wellbeing, amongst farmers and the public more broadly.

PART 2: LIVESTOCK AND CLIMATE CHANGE: THE NEED FOR REASSESSMENT

The second part of this report challenges a widespread belief: that grazing livestock are the worst form of food production for the climate, due to their relatively high land use and greenhouse gas footprints. While these are both key issues, a more holistic approach to measuring climate impact – one that considers emissions, sequestration and the wide range of other key indicators of sustainability together – shows that grazing livestock can play a central role in a food system that works for the climate, as well as nature and human health.

Land use: grazing livestock and woodland expansion

Contrary to what is sometimes argued, we can create more space for trees, whilst maintaining grasslands and grazing livestock as key components of our food system. This could be delivered, to a significant extent, through a much greater integration of trees and livestock, via an expansion of hedgerows and wood pasture. While there are also major benefits to be gained from woodland creation, there are important limits to how and where afforestation should occur.

Addressing greenhouse gas emissions

Adopting a lower-input, pasture-based approach to livestock production, alongside a shift to healthier diets that contain smaller amounts of high quality meat and dairy, could enable a significant reduction in GHG emissions and sequester very large quantities of carbon. But we also need to measure and communicate these impacts in a more holistic manner. This should include a more accurate accounting of methane, which recognises that an ongoing though reduced level of emissions is compatible with a net zero future. Carbon footprint assessments also need to consider a broader range of outputs and sustainability indicators than current emissions and land use intensity metrics typically provide.

RECOMMENDATIONS

If we are to succeed in the transition to farming systems that benefit people and planet, action will be required across the entire food system, informed by an ambitious and holistic food and farming strategy. The recommendations of this report include:

Joined-up government action to deliver a 'land sharing' approach to food production, where policies support farming practices that deliver multiple public goods, as well as a shift to healthy and sustainable diets.

Application of the 'polluter pays' principle, particularly in relation to nitrogen fertiliser and other fossil fuel derived inputs, to incentivise a move away from harmful farming practices.

Adoption by the government of a harmonised approach to measuring the climate, nature and social impacts of farming, enabling better understanding of the full picture of farming outcomes and providing clarity on how and where public money should be spent.

Action by retailers and food companies to establish a long-term business proposition for regenerative systems, reward farmers for the transition, and create clear and accurate labelling for consumers to help differentiate between the animal products which are part of the problem, and those which are part of the solution.

Support from the finance and philanthropic community to 'prime the pump' for the agricultural transition, including funding for participation in farm trials, investment in local food infrastructure and support for farmer knowledge exchange programmes.

More research into regenerative grazing systems, including around how the delivery of multiple ecosystem services can be accounted for. This would help address the evidence gap created by the historic lack of research into biologically based farming systems.

Introduction

There is now broad agreement that our food system is unsustainable, and that current patterns of livestock production and consumption are a major part of the problem. Change, however, is not happening fast enough, in large part due to the lack of consensus around the future role of livestock.

Two perspectives have so far dominated this debate – one which calls for an end to all animal agriculture in favour of plant and/or alternative proteins, and another which aims to satisfy our growing demand for meat and dairy as 'efficiently' as possible through further intensification of livestock production.

While these visions obviously differ in significant ways, broadly speaking they both tend to align with a **'land sparing'** model of land use. This is where, through high-yielding farming methods, as little land as possible is used for agriculture, freeing up the remaining land for nature conservation and other non-agricultural uses. From this perspective, animals raised predominantly outdoors on grass are typically seen as the least sustainable form of food production, because they tend to require more land and produce more greenhouse gas emissions per kilogram of product than other foods.

With a growing global population and a pressing need to avoid further agricultural land expansion, there is little doubt that some degree of land sparing will be required moving forwards. There are, however, various criticisms of the approaches outlined above – concerns around the future viability and environmental impacts of high-yielding intensive farming systems, and their often-poorer standards of animal welfare, being just two examples.

In recognition of these concerns, interest has been growing in a different, **'land sharing'** model. This is where less land is spared from agricultural use, and biodiversity and other 'ecosystem services' are instead supported across the whole farmed landscape, through farming systems based upon biological principles, rather than high inputs of fossil fuel-derived agrochemicals.

Grazing, or ruminant, livestock – in particular, cattle and sheep – have a central role to play in this 'agroecological' approach to food production, and this is ultimately due to their ability to thrive off grass and other types of forage plants humans can't consume. This includes in regenerative cropping systems, built around diverse crop rotations that contain a fertility-building grass and legume phase. These temporary grasslands, or leys, improve soil health and help minimise the need for synthetic fertilisers and pesticides, but because they do not produce human-edible crops, they generally need grazing by livestock.

Grazing livestock reared in low input, pasture-based systems can deliver a range of other key benefits, too. They 'upcycle' human-inedible forage into nutrient dense foods, help maintain biodiversity- and carbon-rich landscapes with huge social and cultural value, and support high standards of animal welfare.

The main criticism levelled against this 'multifunctional' approach to livestock production, as well as biologically based farming more generally, is that it tends to be lower yielding. The concern here is that farming this way at scale would require us to expand our agricultural area and/or import more food – outcomes that would be bad for both the environment and food security. Recent research, however, has shown that this need not be the case. Studies that have modelled the implementation of these systems at scale, including in the UK, have found that we could, in fact, produce enough food to maintain and even improve upon current levels of self-sufficiency, whilst also freeing up land for other uses, like woodland. Crucially, though, this would depend on us wasting less food and aligning our diets with what we can sustainably produce.

This change in diets would likely entail an overall reduction in the number of calories we consume, and a much greater intake of fruit, vegetables and pulses. **But it would also require a significant reduction in the amount of animal products we eat**, particularly when it comes to pork and poultry – driven, mainly, by a major fall in the use of cereal feeds, a move away from imported protein feeds like soya (a leading cause of overseas habitat loss), and an end to permanently housed, intensively stocked production systems. Meat and dairy from low input, pasture-based ruminants would, however, continue to form an important part of the national diet, for the reasons touched on above.

The aim of this report is to explore this positive role, by highlighting the multiple benefits grazing livestock could deliver as part of a UK-wide transformation in farming practice and diets. It builds upon two previous reports by the Sustainable Food Trust: The Hidden Cost of UK Food (2019), which focused on unpacking the financial barriers to this transition; and Feeding Britain from the Ground Up (2022), which modelled the impact on land use, food security and diets of a national transition to biologically based farming.

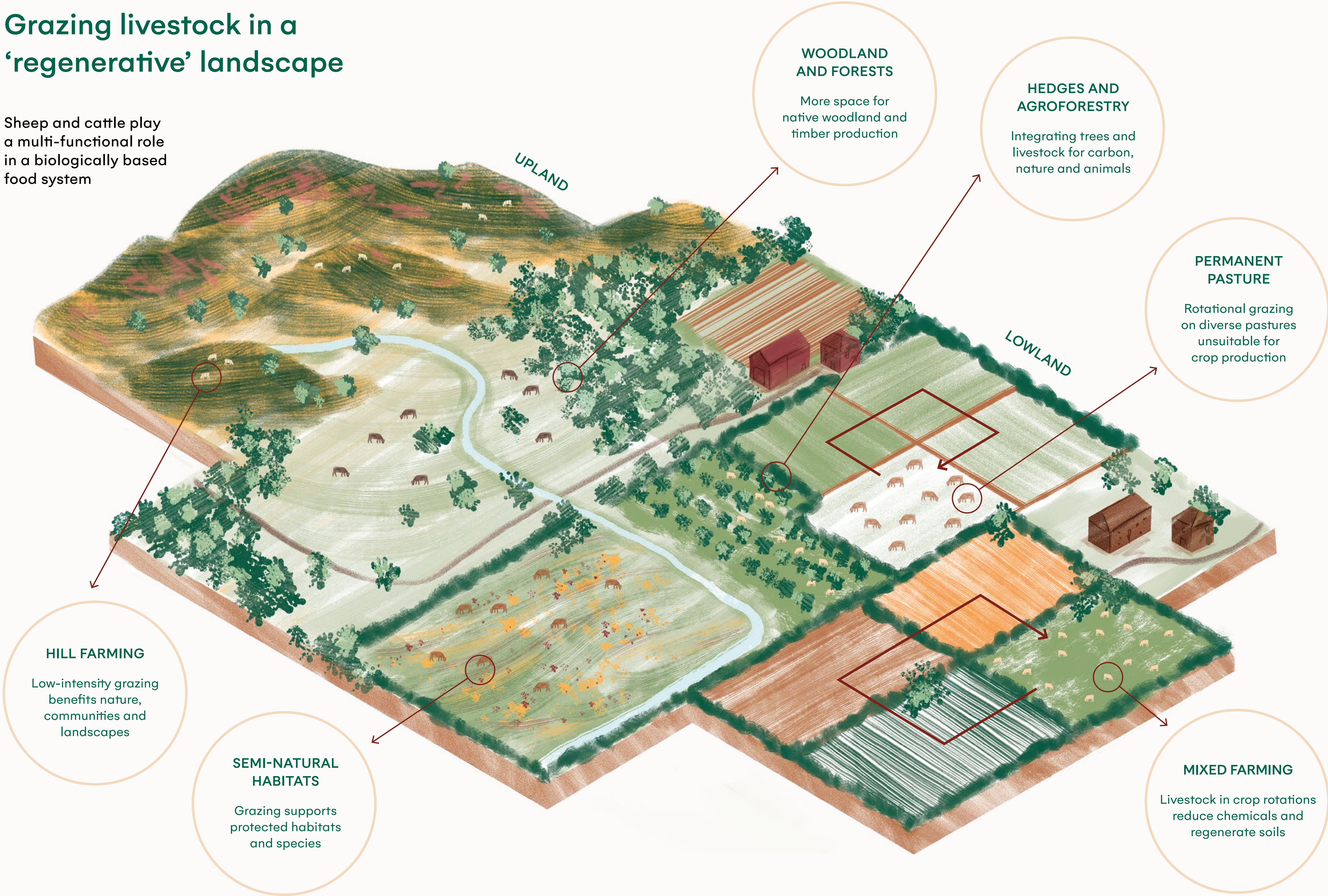
> "Grazing livestock have a central role to play in a regenerative food system, and this is ultimately due to their ability to thrive off grass."

Grazing Livestock is split into two parts. Part 1 explores some of the key benefits and ecosystem services that well-managed ruminants and grasslands can deliver. Part 2 then takes a fresh look at concerns around the climate impact of grazing livestock, and explores how ruminants could play a central role in a more climate-friendly UK food system.

This is a complicated debate, encompassing a host of often tricky environmental, cultural, political and ethical considerations, and so this report does not attempt to cover every issue in detail. We hope, however, that it will help promote a more informed and nuanced conversation that stimulates a re-evaluation of the role of grazing animals in our future food systems.

Grazing livestock in a 'regenerative' landscape

Sheep and cattle play a multi-functional role in a biologically based food system



Part 1

Grasslands, grazing livestock and the delivery of public goods

Part 1 - Summary

Part 1 of this report looks at the central role grazing livestock could play in a regenerative UK food system – one where food production and diets are aligned with what the land can naturally support.

This will require a shift from the largely production-focused systems which remain commonplace today, to a more multifunctional approach, where animals are rotationally grazed on diverse pastures for most or all of the year, with minimal use of synthetic fertilisers, pesticides or arable feed inputs.

The key benefits of this lower input, more pasture-based approach are explored across five chapters:

1.1 REGENERATIVE MIXED FARMING – Examines how grazing livestock can support circular, regenerative cropping systems that do not rely on agrochemicals.

1.2 NUTRITION AND FOOD SECURITY – Assesses the major contribution grazing livestock can make to feeding the UK in a resource-efficient way.

1.3 CARBON STORAGE AND SEQUESTRATION – Discusses the importance of protecting existing carbon stocks, and the significant potential that may exist for additional sequestration above- and below-ground.

1.4 BIODIVERSITY – Explores how lower input, more pasture-based and mixed farming systems benefit wildlife, and the critical importance of grazing animals for many habitats and species.

1.5 RURAL COMMUNITIES AND LANDSCAPES – Highlights some of the key social and cultural benefits provided by grasslands and grazing livestock in the UK.

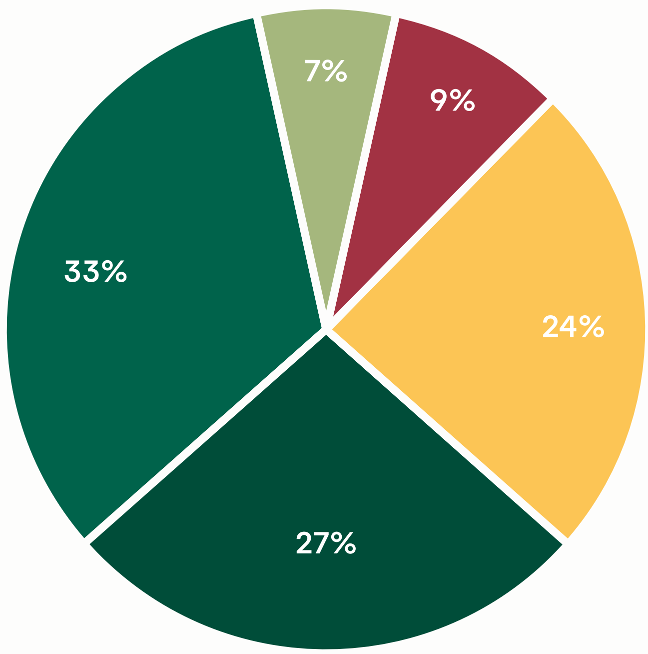
BOX 1

The UK's grasslands – a snapshot

As the infographic on page 14 illustrates, grazing livestock have a central role to play in regeneratively farmed landscapes. There are various reasons for this, but fundamentally, it is because they can harness the many services that grasslands provide to society.

Two thirds of the UK's agricultural area is under grass (Figure 1). In large part, this is because a lot of land is too hilly, or the climate too cool and wet for crop production.[1] But even on land used to grow crops, grasslands are, or at least can be, a key feature. While the UK's grasslands vary in all sorts of ways, they can broadly be divided into three types: **improved pasture, temporary grasslands (or leys)** and **semi-natural grasslands**.

FIGURE 1: CURRENT UK AGRICULTURAL LAND USE*



Around two thirds of the UK's agricultural area is under grass. 'Rough grazing' is largely made up of semi-natural grasslands as well as some heath and moorland.

KEY:
- Temporary grassland
- Crops
- Rough grazing
- Permanent grassland
- Other†

* Using data from Defra (2021)[1]
† e.g. uncropped arable land, woodland


White clover

Permanent pasture refers to any grassland more than five years old, and is termed **'improved'** when some combination of draining, reseeding and fertilising has been carried out to increase productivity. Following the Second World War, many grasslands, especially in the lowlands, were improved in this way – a major change to our landscapes, which delivered large increases in livestock productivity, but at significant cost to the environment.

Temporary grasslands, or leys, are defined as land that has been under grass for less than five consecutive years. They are generally used in rotations that contain at least some arable cropping, and play a key role in cropping systems that do not rely on chemical fertilisers and pesticides (see Chapter 1.1). However, decades of intensification and specialisation mean that leys are now much less common than was once the case.

Today, improved pastures and temporary grasslands make up around half of the area used for grazing in the UK[2], and most are managed in a largely production-focused manner, with limited regard for other aspects of sustainability. Typically, this is defined by the sowing of highly productive ryegrass swards that contain few, if any, other species, and the (often heavy) application of nitrogen fertilisers, as well as manure or slurry. They are either grazed under medium to high stocking rates, often in a continually grazed or 'set stocked' fashion, or are cut for silage multiple times per year. On many intensive dairy and beef farms, animals are also fed large amounts of high-energy arable 'concentrate' feeds.

This fixation on yields has caused major harm to the environment, animal welfare and, in many cases, to farm profitability.[3] **Improved pastures and leys can, however, be managed in a much more sustainable way**, by moving to systems that rely far less on agrochemical and feed inputs, and deliver a wide range of public goods, alongside food. While this 'regenerative' approach generally supports lower yields than the most intensive ruminant farms, it can still deliver high levels of productivity – comparable to or even higher than in some conventional systems.[4] Key to this is encouraging a greater diversity of plant species – crucially, including nitrogen-fixing forage legumes like clover, which minimise or even eliminate the need for synthetic fertiliser. Rotational grazing, where animals are regularly moved to allow pastures periods of rest, is another central feature of regenerative pasture management.

Semi-natural grasslands, heaths and moorlands are quite different to improved pastures and leys. Making up the other half of the UK's grazed area,[2] these are some of our most valuable habitats, each supporting a distinct range of species, some of which can only be found in the UK. They are given the term 'semi-natural' because they have been shaped over millennia by farming – mostly livestock grazing and cutting for hay – but have not been drained, resown or fertilised in recent history, and so retain a largely 'natural' mix of native species. Many semi-natural grasslands have been lost to agricultural intensification, particularly in the lowlands, with those that remain often in a poor state due to both over- and under-grazing (see Chapter 1.4).

Semi-natural grasslands have significant limits on their productivity, and need to be managed sensitively to maintain their diversity. Typically, this means low stocking rates, with grazing (often best delivered by a mix of native breed cattle, sheep and sometimes ponies) carried out at times of the year that best suit the habitat in question.


Snowdonia, Wales

1.1 Regenerative mixed farming

Summary:

- Grazing livestock can play a central role in more circular and resilient cropping systems, that are based on biological principles.
- A key part of these regenerative systems is the fertility-building 'ley' – a period of the rotation where land is sown with a mix of grasses, forage legumes and herbs, instead of crops.
- By naturally fixing nitrogen, increasing soil carbon levels and disrupting pest, weed and disease cycles, leys minimise the need for fossil fuel-intensive synthetic fertilisers and pesticides.
- Grazing livestock generally play a key role under this approach as they enable food production during the fertility building phase, but they provide other benefits too, including the supply of manure, enhanced soil carbon gains, and increased biodiversity.

Until the middle of the 20th century, the UK's countryside was dominated by mixed farms, where crops and livestock were integrated in ways that generally benefited both enterprises. Following the Second World War, however, this started to change, as pressing concerns around food security led to a focus on maximising crop yields, achieved through advances in breeding and the mass availability of chemical fertilisers and pesticides.

As a consequence, mixed farming progressively gave way to more intensive, specialist systems, where crop and livestock production began to be practiced separately.

These twin processes of intensification and specialisation resulted in an extraordinary increase in food production – UK wheat and barley yields, for instance, have quadrupled since the 1940s.[6] But this has come at a major cost to soil, environmental and human health, and been achieved by an approach to arable production that is facing growing concerns over its future viability. Addressing these challenges will require major changes in cropland management, something that grasslands – in the form of fertility-building leys managed by grazing livestock – can play a key role in achieving, as this chapter will explore.

INTENSIVE CROP PRODUCTION – THE PROBLEMS

Intensive, high-input, high-output cropping, where a small number of arable crops are grown year after year, has caused huge harm to the environment. 40-60% of cropland soil organic carbon stocks have been lost due to decades of intensive farming,[7] a decline that is ongoing.[8] As a result, **38% of English and Welsh arable soils are now seriously degraded, at an estimated cost to society of £1.2 billion per year.**[7] This damage has in large part been caused by years of continuous cultivation, though the modern reliance on synthetic nitrogen fertilisers also seems to have contributed.[9]

This is far from the only impact associated with the use of agrochemicals on arable land. Nitrogen fertilisers applied to crops are a major source of air and water pollution, account for 30% of the UK's nitrous oxide emissions and have a large fossil fuel and energy footprint (see Chapter 2.2). Pesticides, meanwhile, are a leading cause of the 60% decline in the number of flying insects and farmland birds seen since 2004 and the 1970s, respectively.[10, 11]

Then there are the many environmental, human health and animal welfare problems associated with intensive livestock production, which, through its heavy reliance on feed grain, is umbilically linked to intensive arable systems. These issues have been exacerbated by the separation of livestock and crop production, which has seen vast amounts of manure and slurry being concentrated in locations far from the croplands that would benefit most from their application. The consequences of this are being felt to devastating effect in some of our most precious terrestrial and freshwater habitats, in the form of soil acidification, the loss of nitrogen-sensitive species, and eutrophication – as briefly touched upon later in the report (Box 16).[12, 13]

There are also serious concerns around the long-term viability of the current conventional approach to crop production and its ability to generate consistently high yields. **A greater frequency and intensity of extreme weather events could reduce crop yields and will require much more emphasis on resilience**, something that the current system lacks, in large part due to the absence of diversity within specialised cropping systems.[14] Pesticide resistance, meanwhile, continues to worsen – for example, herbicide-resistant blackgrass (the UK's most problematic arable weed) already results in yield losses worth £400 million per year, and there are signs that it may now be developing resistance to glyphosate, one of the few remaining chemicals that reliably controls it.[15] There is even a real risk that a business-as-usual approach to crop production will render some fields unproductive – globally, an estimated 16% of conventionally managed cropland soils have lifespans of less than 100 years due to soil erosion.[16]

THE IMPORTANCE OF FERTILITY-BUILDING LEYS

It is clear, then, that significant changes are needed to the way in which the UK's croplands are managed. While this will necessitate a wide variety of actions, shifting from chemically to biologically based farming systems offers perhaps the most transformative potential. The key feature of these is the use of diverse crop rotations. This is where a different crop, or sometimes mix of crops, is sown each season on a plot of land – as illustrated on page 26. The point of a rotation is to build good soil health and fertility, and control pests, diseases and weeds, without having to rely heavily on chemical fertilisers and pesticides. Each phase of the rotation has a critical role to play in achieving this, but in some ways the most important, at least in cropping systems that are looking to minimise their reliance on agrochemicals, is the **fertility-building ley**.

Fertility-building leys form the restorative part of the rotation, providing a period of time when the soil can recover and rebuild the fertility lost during the exploitative crop production phase. Leys can be made up of many different species (see Box 2) but, generally speaking, they consist of a mixture of grasses, forage legumes and sometimes herbs. Each of these elements brings its own benefits – grasses, for instance, can improve soil structure and organic matter levels, while legumes naturally fix nitrogen – which, in combination, generate better structured, more carbon- and nitrogen-rich soils with greater water-holding capacity.

There are two ways in which **fertility-building leys reduce the need for synthetic nitrogen fertiliser**. The first, and by far the most important, is that forage legumes naturally build soil fertility by fixing nitrogen from the atmosphere, creating a 'bank' of plant-available nitrogen in the soil, which can be used by following crops. The use of forage legumes has been shown to drastically reduce the need for synthetic nitrogen fertiliser – not just on organic farms, where it is not used at all, but also on more 'conventional' farms. For instance, a Dutch study found that when grass and legume leys were included in an arable rotation, nitrogen fertiliser use in the following cropping phase was reduced by 50-92%.[17]

Secondly, by providing forage for grazing livestock, leys can generate a supply of nutrient- and carbon-rich manure, which can be applied at points of the rotation when a fertility boost is most needed. This is just one of the direct benefits sheep and cattle can bring to arable systems.

The integration of leys into crop rotations also minimises or eliminates the need for plant protection products – pesticides, herbicides and fungicides – by helping to break the lifecycle of arable pests, weeds and diseases. For instance, introducing grass leys into crop rotations has been demonstrated to offer 70-80% control of blackgrass weeds per year, providing there is no new seeding.[18] Once again, livestock can provide additional benefits here, with their grazing being shown to prevent blackgrass seeding.[19]

The other major benefit provided by the integration of leys into crop rotations is their positive impact on soil health, across a wide range of indicators. **The use of leys has been shown to significantly improve soil structure, increase soil carbon** (an issue returned to in Chapter 1.3) **and improve soil biology**. One study found that a two-year ley increased earthworm abundance to four times that of continuously cropped arable soils, a level similar to that seen under neighbouring permanent pasture.[20] All of these positive changes lead to soils which are much more resilient to extreme weather, have better fertility and produce lower levels of pollution – though care needs to be taken over how a ley is terminated prior to the planting of the next crop, as significant loss of nitrogen from the soil can occur at this stage.

BOX 2

Herbal leys

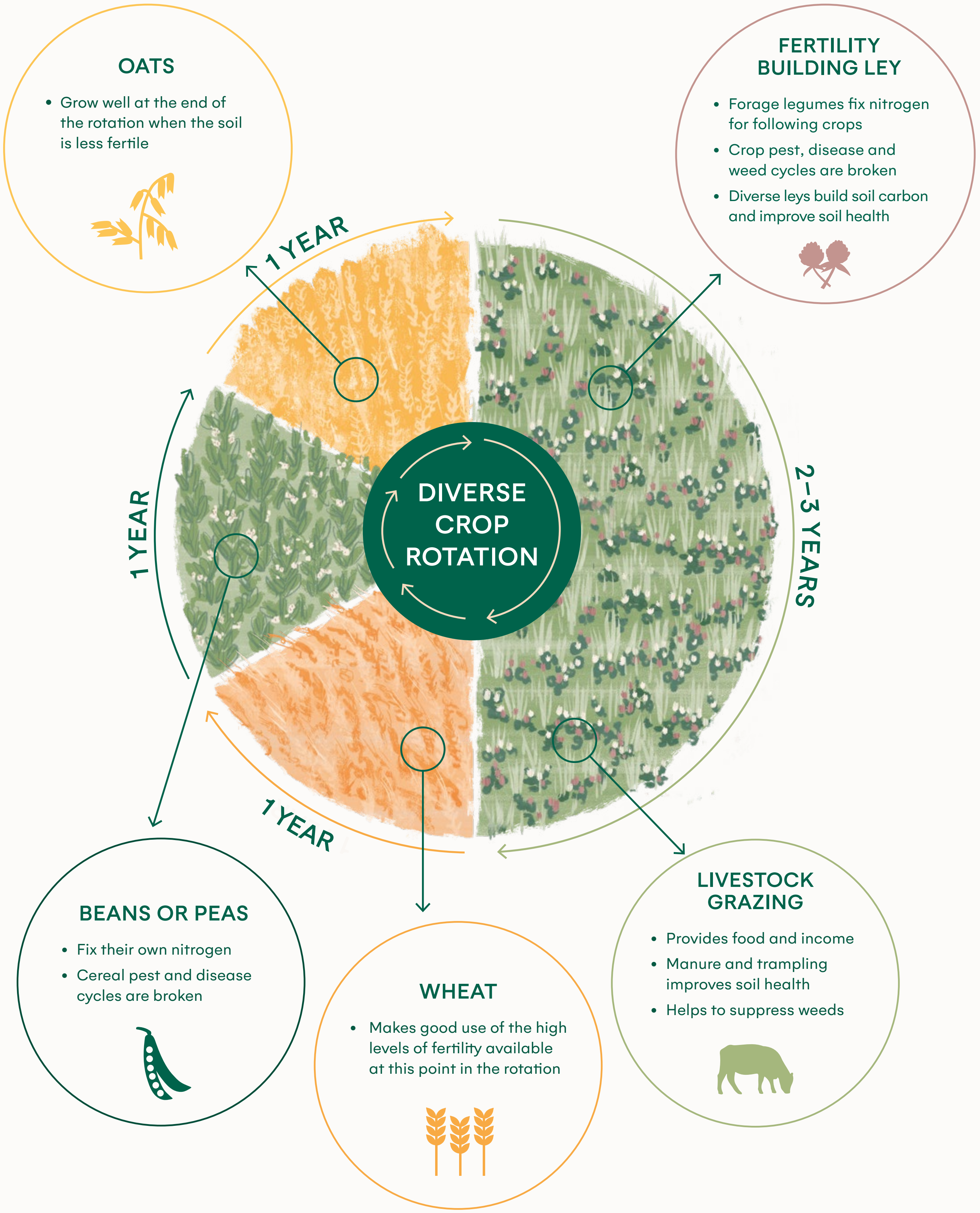
In recent years, there has been growing interest in the potential offered by the use of leys containing a high diversity of species.[5] Often termed multi-species or herbal leys, these commonly include a variety of grasses, deep rooting herbs (such as chicory or plantain) and forage legumes (including clovers, trefoils, lucerne or sainfoin).[21,22] While research is still at a relatively early stage, the evidence gathered to date shows that **their use can bring real benefits to soil health, forage and animal productivity, as well as the climate impact of grazing livestock**, over and above the benefits provided by simple leys that consist mainly of ryegrass.

For example, a series of European experiments found that grasslands where multi-species mixes were used alongside very low nitrogen fertiliser inputs had a much lower proportion of weeds, greater forage productivity and better nitrogen use efficiency (a measure of the percentage of nitrogen inputs that are lost) than single species swards that received much greater amounts of nitrogen fertiliser.[23,24]

In Ireland, meanwhile, research into multi-species swards has found that they can deliver major environmental and agricultural benefits. For instance, they have been found to increase earthworm numbers, reduce beef emissions by 15% (a point we return to in Chapter 2.2), improve resilience to drought and increase animal growth rates and farm profitability.[25]

Grazing livestock in an arable rotation

Sheep and cattle can provide multiple benefits when integrated into mixed rotational farming systems, as in the example below.



MAXIMISING THE VALUE OF LEYS – THE ROLE OF RUMINANTS

Grazing livestock are usually a key component of rotational farming systems, and while there are various reasons for this, the main one is **they enable the production of food, and therefore income, from the otherwise 'unproductive' fertility-building phase of the rotation.**[26] Although it is possible to operate livestock-free rotational systems that contain a fertility-building phase, in practice this is fairly rare away from the very best quality land because, without livestock, having a ley in place for much more than a year comes with too great a production penalty.

Integrating livestock into arable systems can bring a range of other more direct benefits, too. The previous section mentioned how grazing livestock can play a valuable role in managing weeds, such as blackgrass. **They can also bring important benefits for soil health.** For example, sheep are known to return about a quarter of the organic matter that they consume back to the soil via excreta, while the trampling of plant litter and dung into the topsoil by animals also has a positive effect on organic matter levels. As a result, grazed leys typically store 2-20% more soil organic carbon than ones that are cut.[2, 27] Grazing animals have also been found to improve numerous indicators of soil biodiversity, an issue explored further in Chapter 1.4.

Manure brings other benefits for soil health. For instance, a recent study from Rothamsted Research found that applying manure to arable fields generated significant improvements in various soil properties, to the extent that some were similar to those seen in grasslands and woodlands. This included a more open soil structure, allowing oxygen and nutrients to circulate, and higher levels of organic carbon (discussed in Chapter 1.3) and soil nitrogen. Arable soils receiving inorganic fertilisers, meanwhile, retained just half the amount of nitrogen compared to soils


Crops in rotation, Dorset

receiving farmyard manure, with the losses mainly in the form of the greenhouse gas nitrous oxide (discussed in Chapter 2.2). The study also suggested that manure can contribute to the resilience of the system because not all the accumulated nitrogen is incorporated into the next crop, but remains in the soil to support future cropping seasons.[28]

> "grazed leys typically store 2-20% more soil organic carbon than ones that are cut"

Incorporating grazing animals into arable rotations can also bring benefits for farm business profitability and resilience. One reason for this is a reduction in input costs. The UK imports 60% of its nitrogen fertiliser, and following Russia's invasion of Ukraine in 2022, prices skyrocketed, forcing British farmers to spend an estimated £1.62 billion on synthetic fertilisers in 2022 – £1.17 billion more than in 2020.[29] While prices have since fallen, they remain much higher than since the war began, and are likely to remain volatile, given the increasing uncertainties around international trade. Reducing our reliance on imported agrochemicals, and the arable feeds which use them, is therefore likely to become ever-more important for farm profitability and resilience. A move to more diverse crop rotations that include livestock could provide further benefits for farm businesses, increasing the number of income streams and so helping to spread risk.

CHALLENGES AROUND INTEGRATING LEYS AND LIVESTOCK

There are, of course, also significant challenges surrounding the re-integration of animals onto arable land – from a shortage of skills and infrastructure related to the management of livestock, to a lack of small abattoirs. While this report does not set out to address these barriers, some broad recommendations are made in the final chapter.

A more systemic challenge associated with shifting from continuously cultivated to ley-arable systems is the reduction in crop output this entails. This is because the inclusion of leys effectively results in land being taken (temporarily) out of crop production, with the decline in crop output corresponding to the proportion of the rotation in a ley. With an ever-increasing global demand for food, many have viewed this as an issue that precludes the use of leys at scale.[30]

This criticism rests on the assumption that the UK's arable output needs to remain at least as high as it is today, an argument that can be challenged. **By feeding much less grain to livestock, using less land for bioenergy, reducing the amount of food we waste and shifting our diets so that they contain fewer intensively produced livestock products (all beneficial actions in their own right), there would be 'space' for ley-arable rotations to be practiced at much greater scale in the UK than they are today, as indicated by various modelling exercises** – including the SFT's Feeding Britain report.[31-33]

Some arable farmers are, at any rate, already reintroducing grass leys into their rotations, to tackle soil degradation and to deal with the emergence of herbicide-resistant weeds like blackgrass.[34] If these trends, alongside disruptions to trade and increasingly extreme weather, continue as predicted, many farmers may be forced to bring grass back into their rotations. This is an outcome that, were it to happen scale, could deliver major benefits for the environmental sustainability of crop production - benefits explored further in Chapters 1.3 and 1.4.

CASE STUDY

Hafod y Llyn

Teleri Fielden, Ned Feesey and Ianto Glyn

Teleri and Ned's farming business is based upon producing and selling 'Biodiversity Beef' and 'Meadow Glaslyn Lamb', slow grown, pasture-fed red meat.

The native breed beef herd is used for conservation grazing on various National Nature Reserves (NNR), Sites of Special Scientific Interest (SSSI) and Special Areas of Conservation (SAC's), whilst the sheep flock primarily grazes the home farm's floodplain rush pasture and on parkland in the winter.

The livestock live outdoors year-round, generally in one large family group or 'mob', which has benefits for animal welfare, soil health and nature. Biodiversity surveys show around 70 different types of grasses and forbs per field, and nearly 45 different bird species, with 8 being Red-listed and 16 Amber-listed for conservation concern. Grazing by the livestock also helps to control Himalayan Balsam, an invasive, non-native plant species.

A 'closed loop system' is in operation, with no artificial fertiliser or bought-in feed crops required as the livestock are entirely pasture- (and tree-) fed. Insecticides and anti-parasite drugs are not used on the cattle, and by conducting regular faecal egg counts the need for wormers is reduced, the intention being to feed the soil microbiology with the livestock's dung, as opposed to damaging it.

Teleri and Ned are very lucky to have a local, family-run abattoir and butchery 20 minutes away, and they generally sell their meat to the local community.

FARM TYPE

Tenant beef and sheep

LOCATION

Eryri/Snowdonia National Park, North Wales

SIZE

280 rented acres

- 50 acres of woodland
- 50 acres of upland heath and blanket bog
- 140 acres of lowland rush pasture
- 40 acres of parkland
- additional conservation grazing land on grazing licences

"Having a large family group or 'mob' benefits both animal welfare and biodiversity, by not allowing selective grazing, increasing rest periods to allow species to flower and grow their root depth, and enabling the 'trampling effect' to help incorporate organic matter back into the soil."

Teleri Fielden, Ned Feesey

1.2
Nutrition and food security

Summary:

- By converting grass and other inedible feeds into nutrient dense food, grazing livestock can make a central contribution to a more efficient and resilient UK food system.
- In a regeneratively farmed UK, predominantly grass-fed animals could supply a significant proportion of the nation's nutrient requirements – including around 34% of recommended protein intake, 37% of fat intake and 98% of vitamin B_{12} intake, according to modelling by the SFT.
- Climate change and geopolitical instability are increasingly likely to disrupt UK food supplies. Grazing livestock can help mitigate this by producing nutrient-dense foods that complement, rather than compete with, the crops produced from our finite and increasingly degraded arable area – unlike intensive livestock systems that rely heavily on potentially human-edible crops.
- Making the most of livestock is crucial. This includes utilising all parts of the animal and prioritising systems that provide multiple products, including milk, meat and materials like leather and wool.

With a growing global population, ever-increasing threats to food production from climate change and the ongoing encroachment of farming into natural habitats, there is a clear need to transition to farming systems that make a much more efficient use of resources.

So, what role do grazing livestock have to play in achieving this? For some, the answer is that it should be as limited as possible, because ruminants – especially those reared in pasture-based as opposed to intensive systems – tend to require more land in total to produce a given quantity of macronutrients than either monogastric livestock or crops.

This raises some important points, one of which – the question of how we can feed ourselves sustainably whilst increasing the UK's tree cover – is touched on in Chapter 2.1. However, while there are undoubtedly serious problems with the resource-use efficiency and land use requirements of livestock production today, the debate around what constitutes an efficient food system often misses the hugely positive contribution that grazing animals can make to our food supply. **By converting forage and other feeds that humans cannot eat into nutrient-dense foods, grazing animals can deliver major benefits for food security, while improving the resource-efficiency and resilience of our food system** – a service that this chapter will explore in more detail.

THE INEFFICIENCY OF INTENSIVE LIVESTOCK

Animal-source foods (meat, milk and eggs) are a key component of diets across the world. They supply 40% of the global population's protein and significant quantities of other essential nutrients – just one of the reasons why livestock are particularly vital in parts of the Global South, where undernutrition remains a debilitating problem.[35, 46] However, the intensive systems which increasingly supply so much of the world's meat and dairy in many ways also represent a significant drain on the supply of nutrients, and the reason for this is their heavy reliance on potentially human-edible arable crops, in particular cereals.

The practice of feeding arable crops to livestock has increased greatly over the past half century, enabled by the major rise in crop yields achieved through 60 years of agricultural intensification. This, in turn, has driven an increase in livestock production, as the high energy and protein concentrations of arable crops have helped to drive up animal yields and growth rates. It is a practice that has also increasingly favoured pig and poultry production, as these species are relatively more efficient at converting cereals into meat than cattle and sheep.

While this has satisfied – or perhaps, more accurately, fuelled – our increasing appetite for cheap meat, it has come with a host of major environmental and animal welfare problems, highlighted throughout this report. It has also brought a heavy nutritional 'opportunity cost', because all animals (even pigs and poultry) are essentially inefficient at converting crops, which could be eaten directly by humans, into meat, milk and eggs. For every 100 calories of human-edible crops fed to livestock, just 12 are provided in the resulting meat and dairy, as a global average,[37] and even the most 'efficient' meat production systems – intensive chicken and pork units – require 5.1 kg and 4.4 kg respectively of human-edible crop protein to produce 1 kg of meat protein.[38] This means that, at present, many calories and nutrients potentially available for human consumption are instead lost from the food system. The scale of this nutritional opportunity cost is significant: 40% of the world's arable land is currently used to grow feed for livestock – an area which, if it were to be used instead for human food cropping, could provide enough calories for an additional 4 billion people.[39]

Of course, practical constraints, such as difficulties in meeting current quality specifications for milling, mean that the animal feed market often represents the only viable option for crop producers today. It is also important to recognise that feeding a limited quantity of potentially human-edible crops to livestock can deliver some significant benefits for productivity and animal welfare, whilst still enabling a net positive contribution to the supply of macronutrients.[40] Nevertheless, the figures outlined above make it clear that the area of arable land currently used to grow feed crops represents a problematic use of a finite – and as seen in Chapter 1.1, increasingly degraded – resource.

TURNING GRASS INTO NUTRIENT DENSE FOOD

The conclusion that is sometimes drawn from an analysis of the feed-food competition problem is that we should either eat crops directly or use those animals that are the least inefficient at converting crops into food – in other words, pigs and chickens. However, this fails to account for the ability of livestock to produce nutrient-dense foods from grass and other feedstuffs, such as crop by-products and food waste, that humans cannot or do not want to eat – and which, therefore, represent a source of nutrition that complements, rather than competes with, that obtained from crops.

This so-called 'upcycling' of forage is what grazing livestock do best, and in the UK, where most of our agricultural area is unsuitable for crop production, it represents a major contribution to the food supply. **Through meat and milk from grazing livestock, the UK's grasslands currently provide an estimated 21.5 g of protein per person per day, equal to one third of recommended daily intake.**[41] This is clearly a much more significant contribution than the 1% share of protein intake that is commonly claimed in reference to pasture-fed livestock globally – a very low figure that is explained by the fact that it only refers to animals fed entirely on grass, which make up a small percentage of the global herd/flock.[42]

At present, of course, beef and dairy cattle in the UK also consume a significant amount of potentially human edible feed – in fact, the ruminant sector has a similar arable land footprint to that of the pig and poultry sectors.[43] **If, then, we are to shift to a food system where ruminants – and indeed all livestock – provide more nutrients than they consume; and where cropland is mainly used for growing food rather than feed, then a move to lower input, pasture-based systems will be key.**

Achieving this, as well as creating 'space' for lower-yielding but more sustainable cropping practices (see Chapter 1.1) will likely require a shift in the quantity and type of animal-source food consumed in high income countries like the UK, so as to avoid simply substituting production overseas. Previous research has shown **that transitioning to a biologically based, more circular UK food system that delivers healthy diets, will require a major shift away from chicken and pork, due to their heavy reliance on arable feed**,[i] with relatively smaller though still substantial reductions in ruminant production, due to the ability of cattle and sheep to thrive on forage and their important role in making use of fertility-building leys.[32, 33]

The potential nutritional contribution from regenerative ruminants

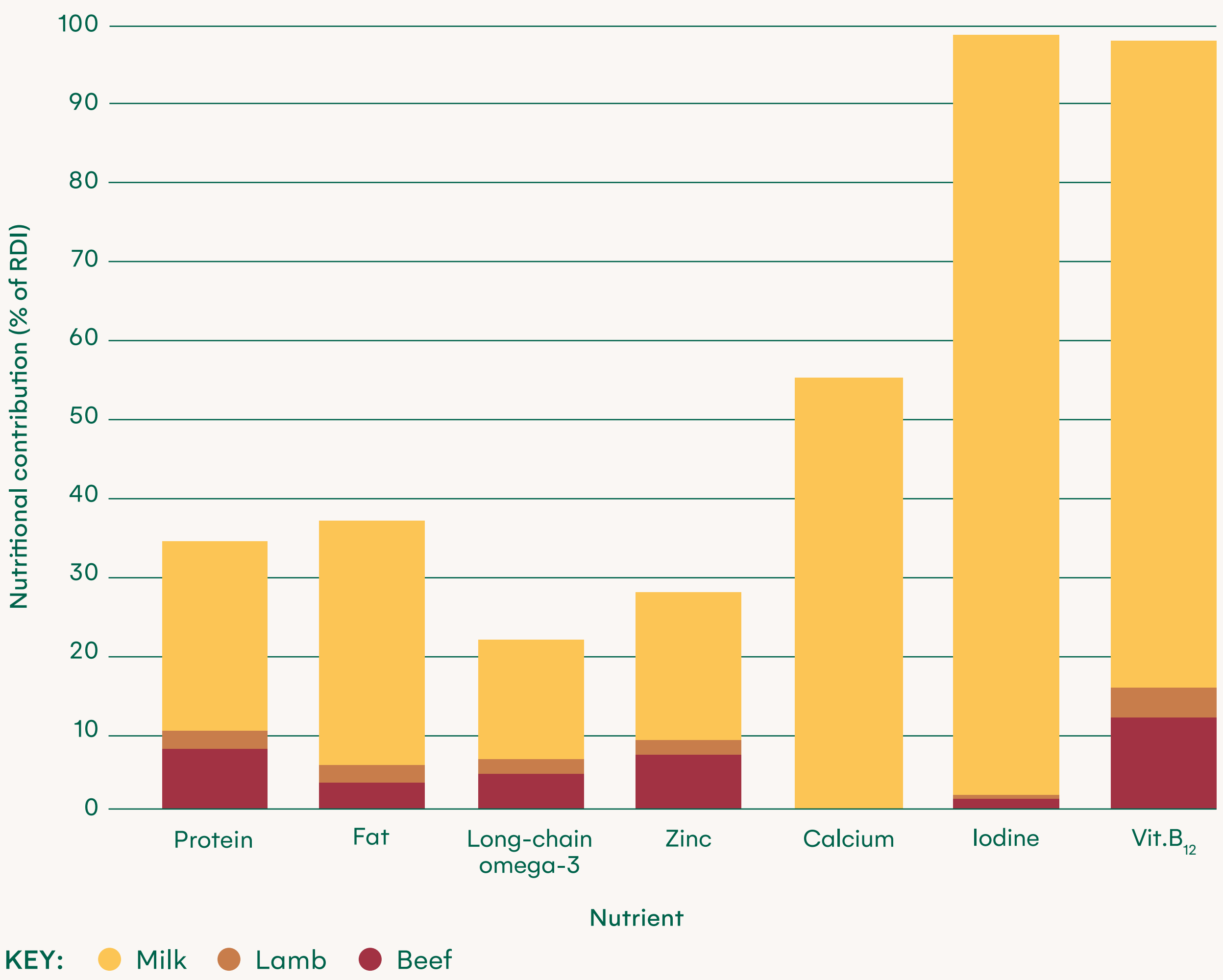
Grazing ruminants could, then, contribute significantly to the supply of several key nutrients in a food system that adopts regenerative principles. For instance, the Sustainable Food Trust's 'Feeding Britain from the Ground Up' report, which explored the land use and food production impacts of a nationwide shift to regenerative farming practices, modelled a 20% reduction in dairy production and a 10% reduction in beef production compared with today.[32] Although this would obviously represent a reasonably large fall in the amount of red meat and dairy in UK diets, this supply would still provide up to 34% of an individual's recommended intake of protein, 98% of vitamin B_{12}, 98% of iodine, 55% of calcium and 28% of zinc from beef, lamb and dairy alone (see Figure 2 overleaf).

This modelled scenario could also provide 37% of our daily fat requirements, as well as 21% of our long-chain omega-3 fatty acid requirements (including DHA and EPA – key nutrients also found in oily fish but not in plants). It is worth noting that these figures are likely underestimates, because they do not account for carcase fat removed during slaughter, some of which can be eaten by humans. While fat is often vilified – and the total amount we consume on average in the UK does need to fall – it is an essential nutrient, and one that we import large quantities of at present, especially in the form of vegetable oils.

At a global scale, meanwhile, studies have shown that rearing livestock on human-inedible feeds alone (forage, crop by-products and food waste) could provide 9-23 g of protein per person per day (around 20-50%

i Pigs and poultry can be reared largely or even exclusively on human inedible feeds (including food waste and, to an extent, forage) and so can play a hugely positive role in a more circular, resource-efficient food system. However, the emphasis on maximum growth rates in intensive systems, combined with the scale of commercial production, means that the vast majority of monogastric production today relies heavily on arable feed – globally, 83% of monogastric feed rations are in competition with human food.[44]

FIGURE 2: POTENTIAL NUTRITIONAL CONTRIBUTION FROM REGENERATIVE RUMINANTS IN THE UK



Regeneratively grazed livestock have the potential to contribute significantly to UK diets. This figure shows the proportion of our Recommended Daily Intake (RDI)[2] of a selection of key nutrients which could be provided by cattle and sheep, were we to transition to a more regenerative UK food system. This is based on modelling carried out in the SFT's Feeding Britain report,[3] which assumed that grazing livestock would be reared mainly on pasture. In this scenario, total UK milk production would be 20% lower, beef production 8% lower and lamb production similar to today.

To calculate these figures, a range of different sources were used.[4] For more information, contact the report authors.

of the world's total requirements), 10% of energy and iron needs, 20% of calcium and zinc requirements, and 75% of vitamin B_{12}.[31]

These are obviously significant numbers, with a key point being that they represent an additional and complementary supply of food to that produced from croplands. Critically, the provision of these nutrients from ruminant meat and dairy would help ease the pressure on what is an increasingly degraded arable land area, as a number of studies have indicated.[31, 45] **For instance, modelling suggests that a global food system where livestock are fed entirely on human-inedible feeds would only require 75% of the arable land needed for a vegan diet,** because of the additional supply of calories and nutrients made available through meat and dairy.[31] This could create more space for lower-yielding but regenerative systems of crop production – something that grazing livestock can play an important role in delivering, as discussed in the previous chapter.

THE NUTRITIONAL VALUE OF MEAT AND MILK FROM PASTURE-BASED SYSTEMS

It's clear, then, that grazing livestock reared largely on human-inedible feeds can make a positive contribution to the nation's food supply. But grass-fed meat and dairy are also valuable from a dietary perspective because of the superior nutritional profiles they tend to have, compared to their conventional grain-fed equivalents. For example, concentrations of vitamins A and E tend to be higher in grass-fed beef,[46] and there are important differences in fat content. Grass-fed beef has 10-60% less saturated fat per 100g of meat[ii], depending on finishing diets and for how long animals are grass-fed, so replacing conventional beef with grass-fed beef aligns with dietary guidelines to limit saturated fat to no more than 10% of energy intake.[59]

Grass-fed beef also has between two and five times more omega-3 than conventional beef. Of particular interest is the sub-group of omega-3 termed 'long-chain'. This is the most biologically active form of omega-3 and is up to three times more abundant in grass-fed beef than conventional.[ii, 60] While there have not been any studies into the health outcomes of replacing conventional beef with grass-fed, it has been demonstrated that eating grass-fed beef increases the levels of long-chain omega-3 in blood plasma – a marker of lower disease risk.[61]

> "Grass-fed meat and dairy tend to have superior nutritional profiles compared to their grain-fed equivalents."

Similar results have been found for dairy. Milk from Pasture for Life certified farms, where cattle are 100% forage-fed, can have up to 92% more omega-3 and 52% more long-chain omega-3, compared to conventional milk from UK supermarkets. In addition, milk from these pasture-based systems has 94% more conjugated linoleic acid, another fat that is almost exclusively found in ruminant meat and dairy, and has been linked to a lower risk of coronary heart disease and certain cancers.[62]

ii These values are based on data from several studies on beef, though other meats show similar differences.[47-58] Most studies report individual fatty acid content as a proportion of total fatty acids. From a nutritional point of view, it is more useful to consider fatty acids per 100 grams meat. When studies have not reported values this way, it has been calculated using total fat content (milligrams fat/100 grams meat) and individual fatty acids as a proportion of total fatty acids (e.g. mg saturated fat / mg total fatty acids).

BOX 3

Comparing the nutritional value of beef and chicken

Chicken is often portrayed as being healthier than beef, but this is a major oversimplification. The argument 'for' chicken is usually based on its lower saturated fat content, but while chicken breast is lean and, therefore, relatively low in saturated fat, the leg can have similar or even greater amounts of saturated fat than grass-fed beef (Table 1).

Furthermore, while many people in the UK do consume too much saturated fat, the issue is more nuanced than is often made out. There are, for instance, a range of saturated fats and not all of them cause an increase in blood cholesterol levels.[63]

The focus on saturated fat has also meant that the high density of micronutrients found in ruminant meat is often overlooked. As shown in Table 1, beef contains significantly higher concentrations of several key micronutrients than chicken – up to 380% more iron, 510% more zinc and 90% more iodine, for instance. On top of this, grass-fed beef has comparable or higher levels of total omega-3, and much higher levels of the biologically active long-chain omega-3, than chicken (Table 1).[iii]

As a result, when the content of a range of micronutrients, as proportions of recommended daily intakes, are combined into a single 'nutrient density score', grass-fed beef can outperform chicken. This has implications when assessing the carbon footprints of beef and chicken, because accounting for nutrient density in lifecycle assessments can significantly reduce the gap between chicken and grass-fed beef, an issue we return to in Chapter 2.4.[65] This is just one of the reasons, touched on throughout this report, why chicken is not necessarily more sustainable than beef, as is commonly claimed.

iii The nutrient content of beef, lamb and dairy is not generally disaggregated by type of production system, so the UK average is used here for all nutrients unless otherwise stated.[64]

TABLE 1: NUTRIENT DENSITY OF GRASS-FED BEEF COMPARED WITH CONVENTIONAL CHICKEN

Nutrient*	Grass-fed beef	Chicken breast	Chicken leg
Fats**			
Total saturated fat (mg)	378 - 1366	439 - 620	1510 - 2512
Total omega-3 (mg)	30 - 154	7 - 66	47 - 149
Long-chain omega-3 (mg)	7 - 105	1 - 21	0 - 26
Minerals			
Iron (mg)	1.9	0.5	0.9
Zinc (mg)	4.1	0.8	1.7
Iodine (µg)	10.4	5.5	5.5
Vitamins			
Folate (µg)	18.3	12.0	7.5
Vitamin B2 (mg)	0.3	0.1	0.2
Vitamin B6 (mg)	0.5	0.6	0.3
Vitamin B12 (µg)	2.0	Trace	1.0

Table 1 shows the nutrient contents of grass-fed beef and conventional chicken per 100 g of raw meat - a comparison that highlights why the "chicken is healthier than beef" narrative is too simplistic, given the greater nutrient density, shown here across almost all categories.

Data drawn from a range of sources.[5] For more information, contact the report authors.

* mg is milligrams; µg is micrograms

** The wide range of values for saturated fat and omega-3 contents can be explained by differences between studies, for example, the use of different breeds, age at slaughter and diet composition.

There are also nutritional differences between ruminant and plant foods. For instance, protein in animal-source foods is generally considered higher quality, because it is more digestible, and contains the full array of essential amino acids (the building blocks of proteins).[66] Bioavailability – how readily micronutrients are absorbed – also differs between animal and plant foods. Iron, for example, has an absorption efficiency of 15-35% when contained in meat but 2-20% in plant sources.[67] Meat has a further an advantage in this regard because it enhances the absorption of iron from plants consumed in the same meal.[68, 69]

None of this means that animal-source foods should replace plants in the diet. Dark green leafy vegetables and pulses are also good sources of iron, for instance, and plants are a much better source of other key micronutrients, like vitamin C. It is, of course, also entirely possible to meet nutrient requirements without meat and dairy.

Still, there are various reasons why the nutritional density of ruminant products matters. For a start, nutrient deficiency is a serious issue in the UK, with certain demographics particularly at risk. For example, 25% of women aged 19-64 have low iron intakes and 15% low iron stores.[70] Beef, lamb and dairy rank as some of the most nutrient-dense foods when it comes to 'priority' micronutrients like iron, zinc and vitamin B_{12} which are commonly lacking in diets.[71] There are, therefore, potentially significant benefits to be had from eating even small quantities of ruminant products – particularly those from pasture-based systems.

GRAZING LIVESTOCK AND NATIONAL FOOD SECURITY

There is also a strong argument from a national food security perspective for making use of the nutrition that our grasslands can provide. Take, for example, the question of how we might achieve a sufficient intake of all the essential amino acids, were we to eliminate all livestock. The only crop grown in globally significant quantities that has a complete amino acid profile comparable to that of animal-source foods is soya, which would, therefore, have to assume a critical role in protein supply. This is particularly true when it comes to achieving a sufficient intake of lysine, the amino acid most difficult to obtain in a plant-based scenario.[72] Soya production could certainly achieve this at a global level – in a sense it already does, it is just that most is currently fed to livestock. However, much of the world's soya production is currently concentrated in Brazil, Argentina and the US.[73] While there is undoubted potential for expansion in temperate climates (including, to some extent, the south of England), it is unlikely that it will become a viable commercial crop in most areas.

A diet that may necessitate imports for the supply of a key nutrient raises some obvious national food security concerns. One plant-based solution is to obtain the full complement of amino acids by consuming cereal grains (that are low in lysine) together with pulses (that are higher in lysine) – **just one of the many environmental and health-related reasons for eating more pulses.** However, there are various practical reasons why it would be difficult, if not impossible, to grow enough British pulses to match the UK's current level of protein self-sufficiency.[74]

Whether it is wise, sustainable or even viable to rely solely on our limited and increasingly degraded arable resource for the supply of all our food, is even more questionable.[75] Climate change will probably have significant impacts on crop yields, both in the UK and abroad, and this in turn will likely lead to increased barriers to trade.[76] With these threats in mind, grazing livestock could play a hugely important role in helping to feed a nation whose land is particularly well-suited to growing forage, whilst helping to relieve the pressure upon what will likely be an increasingly stressed supply of plant foods.

BOX 4

Making the most of livestock

Grazing livestock provide a range of products beyond just meat or milk, though most are seriously undervalued. Increasing our consumption of offal, supporting multi-purpose systems and making better use of hides and wool could therefore deliver major benefits for the productivity, sustainability and economic resilience of the UK's ruminant sector.

Offal

Edible offal is one of the most nutrient-dense foods – liver, for instance, has five times more iron, 14 times more folate and 44 times more vitamin B_{12} than other beef meat.[64] Yet its popularity in the UK has dwindled over recent decades – liver consumption dropped from 36 g per person per week in 1974 to 2 g in 2020/21.[77] Even a moderate increase in offal consumption could therefore provide significant benefits for nutrition.

Greater offal consumption could also reduce the carbon footprint of ruminant production. A Danish study, for example, found that doing so would reduce the carbon footprint per kilogram of beef by 17-23%, because each animals' emissions would be spread across a greater quantity of output.[78] German research, meanwhile, found that increasing offal consumption by 50% by 2050 could reduce emissions from the German meat supply chain by 14%, by enabling the same amount of food to be produced from fewer animals.[79]

Multi-purpose breeds and systems

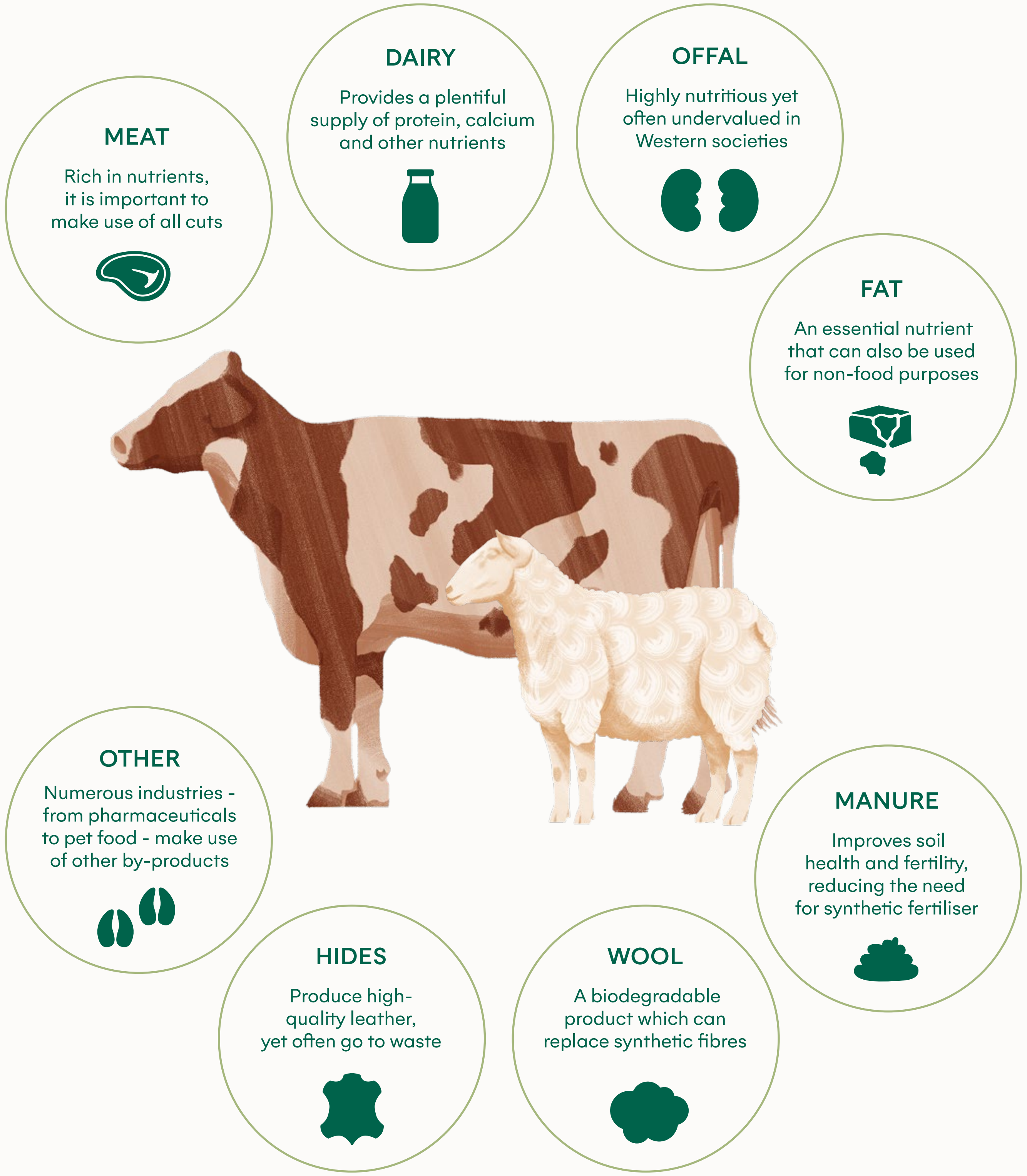
While specialisation in the production of, say, dairy or beef has often resulted in reductions in the emissions or land use intensity of those products,[iv] a more 'multi-purpose' approach can result in lower environmental impacts overall, because an animal's footprint is spread across multiple products instead of one. For instance, research shows that dual purpose herds with moderate yields can produce fewer GHG emissions per kg of milk and beef combined than high yielding specialist systems.[80] An Irish study, meanwhile, found that typical dairy-beef systems yield more human digestible protein than arable production, whereas suckler beef (i.e. beef-only) systems produce less.[81]

With half of the UK's beef already coming from the dairy herd, the benefit of producing beef and milk from the same animal is to some extent already being realised.[82] Practical limits also mean that dual purpose systems are unlikely to become the norm everywhere – dairying, for instance, is difficult to practice commercially in the uplands due to the greater limits on forage production. Nevertheless, there is real potential to improve on the current situation – for instance, by rearing more male dairy calves for beef production.[83]

iv See Chapter 2.4 for a discussion of why measuring the sustainability of a food or farming system solely on the basis of an individual product's carbon or land use footprint is overly-simplistic.

Grazing livestock: beyond meat

Using every part and product of the animal could improve the environmental and economic sustainability of the UK food system, and help create a circular economy



Inspired by 'The Many Products from Cattle', from Sacred Cow (www.sacredcow.info)

BOX 5

Wool – more than a by-product

Wool is a versatile material and was once one of Britain's key industries. However, since its replacement with cheap synthetic fibres, it has been seen as little more than a by- or even waste- product.

The value of wool has plummeted over the last 70 years, from an average price[v] of £14/kilo in 1955 to 89p in 2019, of which the farmer receives just 33p.[84] Income from wool makes up just 3% of revenue from sheep in the UK – a tiny contribution compared with Australia, where wool accounts for 40% of total sheep export value.[84, 85] To counter this loss of income (alongside a fall in subsidies) a transition has occurred away from small, native breeds in favour of high meat-yielding breeds with fast finishing times. Lambs are now often sent to slaughter before their first shearing, and for many farmers, the cost of delivering wool to collection points is not worthwhile, leading to thousands of tonnes going to waste each year.

At the same time, awareness is increasing about the environmental and social impacts of 'fast fashion' and synthetic textiles, which make up 62% of textiles produced globally (wool makes up just 1%).[84, 86] Aside from their reliance on fossil fuels, synthetic textiles are difficult to recycle and contribute to water and soil pollution – 35% of microplastics found in the oceans are derived from synthetic fibres.[87] Making use of wool from sheep reared in regenerative systems could therefore help to reduce the reliance on plastics, offering a high quality, durable and biodegradable alternative.

Wool can replace synthetic materials in other sectors too, helping enable more circular systems.[88] Because it contains a range of key nutrients, which are released slowly as it degrades, low-quality and soiled wool can be made into compost, mulch mats or pellets – replacing commercial fertilisers and peat-based composts in horticulture.[89, 90] Wool has a nitrogen content of around 12%, which is more than some commercial composts, and studies have found it to be effective at regulating soil temperature, supressing weeds and even deterring slugs and snails.[91] Wool also provides effective thermal and sound insulation, meaning it can help meet the increasing need for non-toxic and fire-retardent insulation material for buildings.[92]

> "35% of microplastics found in the oceans are derived from synthetic fibres"

A revival of the UK wool industry could, then, deliver some major benefits, including for farm profitability. However, to enable this transition, various actions are needed. Developing a stronger infrastructure of small and medium sized scouring plants and spinning mills will be a necessity, along with the creation of internal markets for wool.

v RPI-adjusted average auction price

1.3.
Carbon storage and sequestration

Summary:

- The UK's grassland soils store over two billion tonnes of carbon, equivalent to nearly 20 years of UK greenhouse gas emissions. Protecting these stocks is essential to meeting our climate targets.
- Decades of intensive farming have already caused a significant loss of carbon from our farmed landscapes, but a nationwide transition to regenerative practices can help reverse this. Introducing fertility-building leys into crop rotations, integrating trees and livestock, increasing the species diversity of grasslands and rotational grazing could, if adopted together at scale, sequester major quantities of carbon over the coming decades. While more research is needed, this could make a significant contribution to tackling the UK food system's impact on the climate.
- Each of these practices holds the potential to deliver a wide range of other key benefits, including increased resilience to extreme weather – even in instances where sequestration potential is more limited.

Soils are fundamentally important to terrestrial life. They provide us with more than 90% of our food, are home to almost 60% of the world's species, and play a key role in the global water cycle.[93-95] They also have a major influence on the climate, and this, alongside the many other services that healthy soils provide, is in large part due to carbon.

All soils contain carbon, but the quantities stored under grasslands are vast. Globally, grasslands contain a third of all terrestrial carbon, 90% of it in the soil, with temperate grasslands alone holding more carbon than any terrestrial pool other than wetlands and boreal forests.[96, 97] **In the UK, grassland soils hold more than 2 billion tonnes of carbon** – close to twice as much as is stored in our forest stock.[98] For context, that is an amount of carbon almost 19 times greater than the UK's total annual carbon footprint, when expressed in terms of CO_2 equivalents.

Grasslands then, must be protected if we are to have any chance of meeting the UK's climate targets – something that improved grassland management can play a key role in achieving. But this is not just about keeping existing carbon in the soil. **A nationwide transition to biologically based farming systems also offers the potential to sequester significant amounts of carbon** both below and above ground, whilst also delivering wider benefits for sustainability.

This chapter will look at some of the ways in which this might be achieved: through the re-introduction of temporary grass leys into arable rotations, the greater integration of trees and livestock, increasing the diversity of intensively managed pastures, and improved grazing management.

PROTECTING THE UK'S EXISTING CARBON STOCKS

The most important action when it comes to protecting the UK existing carbon stocks is the restoration of peatlands. These are our largest store of carbon, but with around 80% negatively impacted by human activity, they are also a major source of CO_2 emissions.[99] While a range of factors are to blame for this, including arable and horticultural production on lowland peats,[vi, 100, 101] unsustainable livestock practices – intensive grassland management on lowland peats, and overgrazing on upland peats – are one of the leading causes.

How this is remedied depends on the situation. Where degradation is severe, the removal of all grazing is often necessary for at least a period of time. Where peatlands are in a better condition, however, very low levels of grazing are generally not a problem,[102] and can often play an actively positive role in peatland management. For example, well-managed grazing on lowland bogs and fens can prevent the encroachment of trees, which can be problematic from

vi Despite occupying only 2% of the UK's farmland area, lowland peats account for around 20% of the UK's agricultural and land use emissions, and are being lost at a rapid rate due to intensive farming practices. A move to less intensive farming methods in some areas, and a relocation of crop production to non-peat soils in others, is urgently needed to tackle these issues. This has major implications for domestic vegetable production, up to 40% of which occurs on lowland peats – just one of the reasons why horticultural expansion needs to be supported across the UK.

a biodiversity and carbon perspective, while in the uplands, grazing can help in the restoration of blanket bogs.[103, 104]

It is also essential that we prevent the widespread conversion of permanent pasture to cropland – a land use change that typically results in a major loss of carbon. This is an issue that is rarely discussed as a threat within the UK but it does need to be taken seriously. Although most of the UK's grassland area is largely unsuitable for growing crops, many pastures were once under arable production and could be used in this way again – as recently as the end of the Second World War, the UK's arable area was over one million hectares greater than it is today.[106] The current system we have in place to protect against the conversion of pasture to arable is inadequate, and while this means there is a lack of solid data, we know that there has been a significant loss of permanent pasture to arable as recently as 10 years ago, driven by proposed policy changes and high cereal prices.[107]

Some have warned that further loss of permanent pasture to arable production could occur due to changes in diet, with a shift from red meat to chicken consumption and an increase in plant-based eating, potentially encouraging some grazing livestock farmers to transition to crop production.[108] Of course, this risk only applies to those pastures capable of supporting productive cropping systems – what this area might equate to is difficult to quantify, though as outlined above, it is considerable.

The UK's ruminant sector (in particular, beef and dairy) also has its own significant arable footprint, both at home and overseas, and this must be factored into any considerations around the land use consequences of shifts in both production and consumption.

Still, it is vital that the risk of grassland to arable conversion is taken seriously, and that the protection of permanent grasslands is prioritised in policy and legislation.[109] Incentivising a shift to a more regenerative approach to grazing management, as part of a move away from the production and consumption of grain-fed livestock products, could help with this, preventing the further loss of carbon from our farmed area.

REBUILDING LOST CARBON STOCKS

While there is widespread agreement that protecting our existing carbon stocks is essential, there continues to be debate around how far we can go in sequestering more carbon across the UK's farmed area.[30] This is especially true for grassland and grazing livestock management, where extreme claims have fuelled a polarised debate.[110]

Most studies do suggest that, globally, **changes in grassland and grazing management offer a meaningful level of carbon sequestration potential**, and this has been recognised by the Intergovernmental Panel on Climate Change (IPCC).[96, 111-114] In the UK, however, the Climate Change Committee (CCC), which advises the government on how to reach net zero, has not included any significant scope for further soil carbon sequestration on British farmland in their modelling.[115]

There are various reasons for this lack of agreement. Soils are complex structures whose dynamics are still far from fully understood, and there has been a chronic lack of research into many of the agroecological farming practices that may offer meaningful sequestration potential.[116] Where the evidence is stronger (as it is for the inclusion of leys in arable rotations, for example) the practical potential has often been considered limited, mainly due to the fall in crop yields that would likely result from the introduction of agroecology at scale. Many also point out that significant carbon gains are generally only possible up to a point and can be lost following a change in management (see Box 6 on page 48).

A number of points can be made in response. First, it is becoming increasingly likely that a food system transformation, involving a shift to diets lower in calories and animal-source foods, is going to be necessary. Under this scenario, carbon-sequestering but lower-yielding farming practices have much greater potential to be applied at scale, without the risk of offshoring.

It is also important to remember that the UK's agricultural soils have lost vast amounts of carbon. The situation is worst in arable areas: an estimated 40-60% of cropland soil organic carbon stocks have been lost due to decades of continuous cropping.[6] While grassland soils are in a better state, with 'only' 7% of pasture thought to be degraded,[117] the intensification of grassland management appears to have resulted in a major loss of carbon across millions of hectares of pasture too, including from deep in the soil.[118] Our farmed landscapes also store much less carbon above ground than was once the case, due to the loss of hedgerows and, in earlier centuries, wood pasture.

From a purely physical perspective, then, many of the **UK's farmed landscapes have the potential to store much more carbon than they do at present**. Enabling the farming transition required to deliver some of this potential will be challenging, for reasons explored throughout this report. If we can achieve this, though, the benefits for carbon – and sustainability more broadly – could be significant.

Building soil carbon through rotational grazing

vii Arable soils generally have very low levels of soil organic carbon (SOC), sitting at around 43.2 tonnes of carbon per hectare to a 15 cm depth in the UK.[105] Permanent grasslands, on the other hand, have much higher levels of soil carbon (64.6 tonnes per hectare on improved pasture, and higher still on unimproved ones), thanks to their lack of regular tillage and much denser root networks.[105] This also helps foster a thriving soil food web, which is increasingly recognised as having a vital role to play in the soil carbon cycle and soil health more generally. These, it should be noted, are conservative figures – we know that huge amounts of carbon are stored further down the soil profile, and land use has an impact on the size of these stocks – a key point, which is often ignored in studies and discussions around soil carbon.

BOX 6

Soil carbon saturation and reversibility

One of the biggest issues in the debate around soil carbon sequestration is the concept of soil carbon saturation. This is a complicated topic that is still far from fully understood, and which we only outline briefly here. In short, though, this is where the stable pool of carbon that is bound to soil minerals – mineral-associated organic carbon or MAOC – reaches a limit beyond which further increases cannot occur, as all of the soil minerals have become 'saturated' with carbon.[119] There are caveats to this: some minerals appear to have a much greater binding capacity (and therefore a higher saturation point) than average, and recent research suggests that the mineral content of the soil may not be as hard a limiting factor as previously thought.[120, 121] Still, it is clear that mineral soils have a point at which their potential to store additional MAOC becomes limited, with the rate of sequestration slowing as this point is approached.[119]

Some have argued that this means that soil carbon sequestration has only very limited value as a mitigation strategy, especially as any carbon gains are easily reversible due to changes in management or climate – the latter being a potentially serious issue as the climate destabilises.[122] While these are important considerations, and there are undoubtedly limits to soil carbon sequestration, three points are worth making. First, particulate organic matter, or POM (the less-protected, shorter-lived carbon pool derived from plant remains) has no saturation point because it does not rely on the presence of minerals.[123] This means that there is the potential, at least theoretically, for soils to sequester some carbon even when they have become saturated with MAOC – an avenue for which there is evidence, though much more research is required.[119]

Second, concerns around saturation, permanence and reversibility also apply, at least to some extent, to afforestation, yet tree planting is widely seen as having an important role to play in achieving net zero. The point being that carbon sequestration on agricultural land could potentially make a valuable contribution to tackling climate change, providing these limitations are properly accounted for.

Finally, given the length of time it can take for soils to become saturated with carbon,[124] and the extent to which many soils are currently below their sequestration potential, sink saturation may not be as much of a limiting factor as it is sometimes made out to be – at least, not over the next two or three decades. Across Europe, for instance, it has been estimated that 80% of grassland top soils are below their MAOC sequestration capacity and,[119] as touched on earlier in this chapter, we know that this is also the case for most croplands – and many grasslands – in the UK, given the significant amounts of carbon lost over the last century through intensive management and exploitative rotations.[6, 118]

CARBON SEQUESTRATION UNDER DIVERSE GRASSLANDS

As outlined in Box 1, the majority of the UK's improved pastures today are characterised by species-poor ryegrass swards, reliant on applications of synthetic fertiliser. This is an approach associated with various environmental problems, but which remains commonplace due to the high levels of forage productivity it typically delivers. Recently, however, there has been growing interest in the potential offered by pastures that have greater plant diversity – the benefits of which for forage and livestock productivity, animal welfare, biodiversity, nitrogen losses and more are touched on throughout this report.

Increasing the number of plant species in pastures has also been shown to improve grassland soil carbon stocks. **Globally, studies suggest that carbon levels are 15-20% higher in soils under species-rich pastures compared with those that are species-poor.**[125] This is a trend that has been observed in parts of Europe with similar climates to the UK. In the Netherlands, for instance, a study found that soil carbon stocks were 18% higher when multi-species mixtures were grown instead of monocultures, which in turn drove up pasture productivity[126] – a positive relationship which has also been observed in the long-term Cedar Creek experiment in the US.[127] Even greater increases have been seen in a long-term experiment in Germany, where studies found that soil carbon stocks were 20-30% higher in diverse pastures compared with species-poor ones.[128, 129]

While having a high diversity of species appears to be beneficial in its own right, results from a number of studies suggest that having a diversity of plant *groups* is key.[130]

Forage legumes, in particular, have often been found to have a positive impact on soil carbon, believed to be because their ability to fix nitrogen increases biomass production and therefore carbon inputs, and because nitrogen helps promote storage of more stable forms of soil carbon.[viii, 131] Globally, it has been estimated that introducing forage legumes into pasture has the potential to sequester 203 million tonnes of CO_2 per year,[112] and there is evidence for this positive effect from the UK too. For instance, a grassland restoration experiment in the Yorkshire Dales found that by far the most significant carbon gains were achieved with the inclusion of red clover, while another experiment in Northumberland found similar results with white clover and bird's-foot trefoil.[130, 132]

"Globally, it has been estimated that introducing forage legumes into pasture has the potential to sequester 203 million tonnes of CO_2 per year, and there is evidence for this positive effect from the UK too"

viii In swards containing very high proportions of forage legumes, some of these carbon gains can be cancelled out by increased nitrous oxide emissions. However, this is more than offset by the fact that legumes reduce or even replace the need for nitrogen fertiliser.

BOX 7

The importance of soil carbon at greater depths

There is some evidence to suggest that improving the diversity of pastures might increase carbon stocks at greater soil depths, through the presence of deeper-rooting species. While direct evidence for this in temperate climates is currently limited, it is a credible proposition. **Fifty percent or more of the total amount of carbon stored in soils is held in the subsoil** (below around 30 cm of depth),[133] and intensively managed grasslands in the UK have been found to hold far less carbon in the subsoil than more extensively managed ones, demonstrating that this deep carbon is influenced by farming practice.[118] While more research is needed to gain a better picture of why this is, we should be measuring and accounting for carbon held in the subsoil wherever possible – something which is rarely done at present.[134]

GRAZING MANAGEMENT AND SOIL CARBON

Continuous grazing or set stocking (where animals are kept on the same piece of ground over most or all of the grazing period) is a traditional approach to grazing management still widely practiced today. While there is some evidence from other parts of the world to show that certain types of continuous grazing can bring benefits for soil carbon, most studies have found that in temperate regions it leads to lower soil carbon stocks than on ungrazed land (though it is worth noting that in studies where the intensity of grazing is measured, light grazing is generally found to have a less negative impact).[135-140]

Continuous grazing can also have negative impacts on biodiversity and soil health, and often results in an inefficient use of forage. In recognition of this, a range of management approaches which fall under the term 'rotational grazing' have been developed over recent decades, and it is these which should offer scope for soil carbon gains.

In rotational grazing systems, livestock are grazed in a field or paddock for a limited period, before being moved on to a new area, allowing the land ample time to recover before it is grazed again – the aim being to mimic the movement of wild herbivores.[ix] For years, there has been a growing body of anecdotal evidence from farms to suggest that rotational grazing can deliver benefits for the environment, as well as for productivity and profitability. Now, studies are beginning to provide data that supports many of these observations. Benefits for biodiversity[141] and various measures of soil health have been seen,[116] alongside increased productivity.[142, 143] For instance, recent research from Rothamsted found that cell grazing (a type of rotational grazing where animals are moved every 1-2 days) led to a 40% increase in forage production and 140% more liveweight reared per hectare than the comparative continuous grazing system.[144]

There is also growing evidence to show that rotational grazing can improve soil carbon levels. While more research is needed to understand exactly how, this is at least partly due to the encouragement of greater biomass production (through vegetation growth) which increases carbon inputs, while trampling of vegetation into the soil and increased plant species diversity are also likely to bring benefits.[143] Recent global meta-analyses have found that rotationally grazed grasslands have soil organic carbon contents that are on average around 20% higher than continuously grazed areas (though one review found that rotationally grazed plots had similar soil organic contents to ungrazed plots).[137, 139] Individual studies from the US, meanwhile, have found that switching from conventional to rotational grazing can result in high rates of carbon sequestration for a period of time,[145] with one even finding that sufficient carbon was being sequestered to offset all the greenhouse gas emissions of the grazing system under investigation.[146]

There are caveats to these findings. Not every study has found benefits for soil carbon,[147] and some have encountered trade-offs.[148, 149] In some of the studies that have found a positive effect, there are methodological limitations which need consideration.[x] Then there is the problem that many studies to date have not adequately captured the highly complex nature of grazing management.[152] But perhaps the biggest issue, from a UK perspective, is that most of the peer-reviewed evidence comes from quite different climates to the UK – a gap that needs to be addressed.

Rotational grazing, Cornwall

ix What rotational grazing looks like in practice varies considerably, with the stocking density and the length of time given over to the grazing and rest periods all dependant on the circumstances and objectives of the farmer. However, while these differences can have a major influence on management outcomes, they are often not elucidated in what is a fairly limited evidence base. For this reason, rotational grazing is used here as a catch-all term that brings together what can, in practice, be quite different management approaches – something which practitioners and researchers have called for greater clarity over.

x For example, some have been conducted on formerly degraded arable land,[150] while others have been conducted over relatively short timescales (<five years).[146] Results from modelling studies, meanwhile, are not as robust as field experiments.[151]

This is now beginning to happen, and the evidence emerging from temperate regions is encouraging. A study from the Basque country found that grazing sheep in a rotation which included long rest periods resulted in a 3.6% increase in soil organic carbon stocks in topsoil over six years when compared with a conventional grazing rotation – a rate of accumulation that surpassed the '4 per 1000' target set at COP21.[xi, 153] A number of experiments are also underway on permanent pasture in the south and west of England.[154] This includes the Rothamsted study into cell grazing mentioned on the previous page, where after four years, a 5 tonne per hectare increase in soil organic carbon stocks (1.24 tonnes per year) was observed under the cell grazing treatment,[155] compared with a 2 tonne per hectare decrease under the set stocking treatment. This is a promising finding, which other ongoing research projects (such as those led by Farm Carbon Toolkit and FAI Farms) appear to be seeing too.[156, 157]

Add these findings to the unpublished data showing significant soil carbon gains under permanent pasture that some farms have collected (e.g. the Ethical Dairy in Galloway),[158] and **it is clear that improved grazing management merits further attention from a soil carbon perspective.** However, much more high-quality research is required – research that accounts for the complex and adaptive nature of successful grazing systems, and which moves beyond unhelpfully simplistic 'one size fits all' metrics to clearer measures of grassland management, such as grazing frequency, duration, timing and intensity.[152]

INTEGRATING GRASSLANDS INTO ARABLE ROTATIONS

As explained on page 46, cropland soils have much lower levels of carbon than grassland soils – a key reason why the UK needs to avoid the conversion of grasslands to arable production. Might, then, converting arable land to grass deliver benefits for the climate? It can certainly lead to rapid gains in soil carbon – across Europe, the reversion of cropland to grassland through agricultural abandonment has resulted in a significant amount of carbon sequestration over the past century.[159, 160] However, given the limited amount of arable land at our disposal and a growing human population, converting productive cropland to permanent pasture is unlikely to be a viable solution at scale – though in certain circumstances, for example where land has become grossly degraded or is increasingly difficult to crop due to climate change, this could deliver major benefits.

A more viable means of getting grass back into arable landscapes is the introduction of temporary grass leys into crop rotations. **The central importance of leys to biologically based cropping systems is explained in Chapter 1.1, but one of their key benefits is the increase in soil carbon stocks they deliver**, compared with continuously cultivated arable systems.[27]

There is good evidence for this from across the world,[30, 161-163] but one of the best examples comes from the long-term Woburn ley-arable experiment in Hertfordshire.[164] Over the course of 70 years, soil carbon stocks under continuously cultivated arable soils at Woburn fell from 36.9 tonnes per hectare to 35.5 tonnes, but a rotation consisting of a three-year ley followed by two years of cropping saw soil carbon stocks rise to over 45 tonnes per hectare. Almost all of this increase occurred over the first 30 years after the ley was introduced, suggesting that this is the length of time needed for a steady state of soil organic carbon to be reached in this rotation.

xi This is an aspirational goal, based on the simple calculation that an annual 0.4% increase in the world's soil organic carbon stocks would sequester an amount of carbon equivalent to all manmade GHG emissions. While some have questioned whether this is achievable in practice at a global level, the target has helped galvanise interest in the potential for soil carbon sequestration, partly as a mitigation tool, but also as a means of improving soil health and farm resilience.

The introduction of a rotation consisting of an eight-year ley followed by two-years of cropping resulted in even further soil organic carbon gains, reaching 51.69 tonnes of carbon per hectare.

These results highlight an important point, which is that the greater the percentage of the rotation under grass, **the greater the increase in soil carbon**.[165] There is, however, an obvious trade-off here, which is that as a crop rotation becomes more ley-dominated, it produces less crop output – an outcome that would result in a reduction in national cereal production, if leys were introduced at scale. This issue is addressed in Chapters 1.1 and 1.2, but in short, the argument that we need to continue producing as many crops as we do today can be challenged. We know that by feeding much less grain to livestock, using less land for bioenergy, reducing the amount of food we waste and shifting our diets so that they contain fewer intensively produced livestock products (all of which would be beneficial actions in their own right), there would be 'space' for ley-arable rotations to be practiced at scale.[32, 33]

If this can be achieved, then the impact on soil carbon would be significant. For instance, a recent modelling study found that **somewhere between 2.2 and 10.6 million tonnes of CO_2 could be sequestered per year in the UK through the use of temporary leys.**[166] It could be argued that the upper-bound figure modelled here is unlikely to be achievable in practice, since it assumes a rotation consisting of only one year of cropping to two years of leys - a balance that would likely lead to too great a fall in crop production, if replicated nationwide. However, the lower-bound figure, based on a rotation of two years of cropping to one year of ley, still represents a very meaningful level of sequestration potential. It's also worth pointing out that these figures may be quite conservative. **At Yatesbury House Farm in Wiltshire, for example (see page 58) soil sampling showed that, over the course of five years, soil organic matter increased by at least 1.21% in the top 10 cm, a rate of increase that has enabled the farm to sequester ten times more carbon than it emits,** far exceeding the ambitions of the global '4 per 1000' initiative agreed at COP21 (see footnote on previous page).[167, 168]

There is also evidence to show that the introduction of grazing animals can enhance the carbon benefits of fertility-building leys, with research showing that grazed leys store 2-20% more soil organic carbon than ones which are cut – just one of the reasons why the re-integration of ruminants into the UK's arable areas could deliver enormous benefits for sustainability.[164]

> "The introduction of grazing animals can enhance the carbon benefits of fertility-building leys."

Of course, these carbon gains would need to be balanced against the emissions produced by the introduction of ruminants to arable areas. At a UK level, this could lead to a net warming impact if there were a significant increase in the national herd size. However, as long as any increase in ruminant numbers in arable areas is accompanied by a major reduction in the number of intensively reared cattle, the overall impact on the climate (as well as on biodiversity, animal welfare and air and water pollution, amongst other things) would likely be hugely beneficial. The topic of GHG emissions is explored further, in Part 2.

THE ROLE OF HEDGEROWS AND FARMLAND TREES

There is also major scope to sequester carbon through the integration of trees and livestock – or 'agroforestry'.

Trees have been a central part of our farmed landscapes for millennia, providing feed and shelter for animals, amongst many other services. Today, hedgerows and field margin trees are the UK's main form of agroforestry. Until a few centuries ago, however, wood pasture – a semi-open mosaic of trees and grazed grassland – was also a common feature of the British landscape.[169] Very little now remains, but recently, the integration of trees within pasture – ranging from rewilding projects to more production-focussed 'silvopasture' systems – has attracted much more interest, thanks to the wide variety of benefits this can provide (see pages 54 and 66).

One of these benefits is the potential to sequester carbon. To date, relatively little work has been done to quantify this and estimates vary widely, depending on the assumed planting density and environmental conditions. Nevertheless, **existing modelling studies show that silvopasture offers substantial sequestration potential** (Table 2).

As with many other agroecological practices, achieving uptake at scale will require government support and a cultural shift in both the forestry and farming sectors. Putting, say, 10% of grassland into silvopasture with reasonably high tree densities (which deliver greater rates of carbon sequestration) will also require a reduction in livestock numbers in some instances,[xii] due to the reduction in grazing area. While this will be achievable, even beneficial, in many cases (e.g. where stocking rates currently exceed the natural carrying capacity of the land), it may be a challenge for farms that cannot afford to lose much of their forage resource.

TABLE 2: THE POTENTIAL OF SILVOPASTURE TO STORE CARBON IN THE UK

Source	Sequestration potential (million tonnes CO_2 per year)	Time frame	As a percentage of GHG emissions from UK livestock[6]
Woodland Trust[7]	13	By 2060	45%
ClimateXChange[8]	8.97-13.3*	By 2050	31-46%
Climate Change Committee[9]	5.477	By 2050	19%

Table 2 highlights the significant potential to sequester carbon through silvopasture (the integration of trees and livestock on the same ground) in the UK. These figures assume that 10% of the UK's grassland area would be used for silvopasture. The wide range of values is explained by differing assumptions. The Climate Change Committee figures, for instance, only account for above-ground biomass (trees), whereas the ClimateXChange and Woodland Trust figures include the impact on soil carbon.

* Calculated using per hectare figures given in the referenced source

Hedgerows, because they are limited to the margins of fields, come with less of a forage trade-off. While this means they do not have the same sequestration potential as silvopasture systems that integrate trees within pasture, they are still hugely carbon-rich: mature hedges hold on average close to 70 tonnes of carbon per hectare once all the above- and below-ground carbon stocks are accounted for.[171]

Sadly, around 50% of British hedgerows have been lost since the Second World War, mostly in arable areas.[172] As a result, grassland landscapes today have a greater density of hedgerows than arable ones (5.25 versus 3.34 km/km2),[173] and this means greater levels of carbon storage. For instance, research has shown that landscapes with a high density of hedgerows contain 33 tonnes more soil carbon per hectare than those with a low density – and that is without accounting for carbon in the vegetation above ground, where at least half of all hedgerow carbon tends to be stored.[174]

Reversing the loss of hedgerows, and improving the management of those that remain, could therefore deliver a meaningful level of carbon sequestration, alongside multiple other benefits. CPRE, The Countryside Charity, estimate that a 40% increase in hedgerow length (recommended by the Climate Change Committee) could sequester 5 million tonnes of carbon over 30 years, equivalent to about 1.3% of the UK's total agricultural emissions each year.[172]

Research from Leeds University, meanwhile, has found that over the course of 50 years, hedgerow expansion in England could sequester an amount of carbon equivalent to 4.7% of English agricultural emissions – a figure that could rise to 6.4% if newly planted hedgerows had a wider average width than today.[175] Notably, these figures do not incorporate the considerable sequestration potential of field margin trees, many of which have been lost over the past few decades.[176]

Hedgerows offer another climate mitigation benefit, through the provision of woodchip for bioenergy. One study found that if 10-30% of UK hedgerows were managed for this purpose, between 0.3 and 0.9 million tonnes of CO_2 emissions could be saved per year through the replacement of heating oil.[173] Add this to the sequestration potential modelled by CPRE, and improving the length and management of the UK's hedgerows could hold a total mitigation potential of between 0.917 and 1.517 million tonnes of CO_2 per year. Of course, some of this potential relates to hedgerows on arable land, so if we subtract an amount proportionate to the current ratio of arable to grassland hedgerow area, then that leaves 0.569 to 0.94 million tonnes of mitigation potential that could be apportioned to the grazing livestock sector – equivalent to between 2-3% of the UK's current annual livestock emissions.

xii The Woodland Trust estimated that putting 10% of the UK's grassland area under silvopasture would require a 5% reduction in livestock production.[170]

BOX 8

The benefits of agroforestry

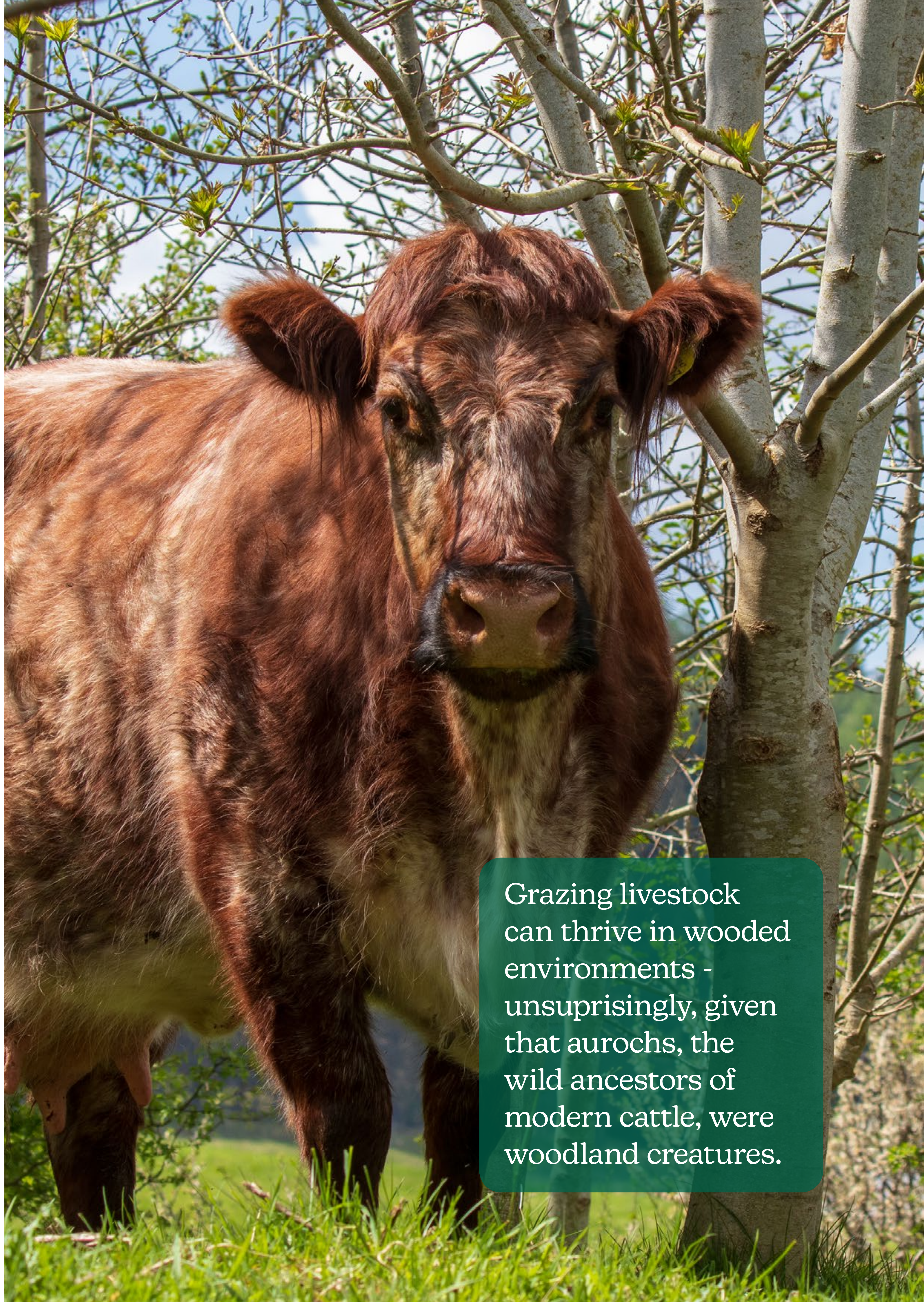
Trees and livestock have often been seen as incompatible, but their integration actually offers a wide range of benefits that could prove transformative, if applied at scale.

One of these benefits is improved animal welfare. By providing shelter from wind and rain, trees reduce animals' energy expenditure and consequently feed requirements, and can lengthen the amount of time they are able to spend outdoors in winter months. In the summer, meanwhile, trees provide shade, helping animals to avoid heat stress, a benefit that will only increase in importance as extreme temperatures become more common.[170, 177] Planting a range of tree species also encourages natural behaviours, a key aspect of good animal welfare. Animals have a greater choice in what they eat, and, it would appear, are given the opportunity to self-medicate (for example, by seeking out willow which contains salicin, for pain relief).[178-180] Hedgerows can also support biosecurity by acting as a more effective physical barrier than fences between neighbouring farms, thereby preventing nose-to-nose contact and reducing disease transmission between herds.[170, 177]

These improvements to welfare often translate into improvements for farm profitability and resilience, including through reduced veterinary and feed costs. But agroforestry can bring other benefits from a farm business perspective. For instance, by creating a more favourable microclimate and improving soil structure, trees can extend the grass growing season, thereby reducing feed requirements. They also offer the potential for additional income streams – timber and fruit production being two obvious examples – which can help to spread financial risk.[170, 177]

> "Planting a range of tree species also encourages natural behaviours, a key aspect of good animal welfare"

The implementation of agroforestry at scale could also deliver enormous environmental benefits – and not just for carbon sequestration (discussed earlier in this chapter) and biodiversity (see Chapter 1.4). For instance, trees can improve field drainage and reduce surface water runoff, protecting the soil from erosion and reducing flood risk. Trees are also 'nutrient sinks', meaning they minimise nutrient leaching from the soil, which is important not only for retaining soil nutrients for productivity, but also for protecting water quality and preventing eutrophication of freshwaters.[170,177]



Grazing livestock can thrive in wooded environments - unsuprisingly, given that aurochs, the wild ancestors of modern cattle, were woodland creatures.

THE SEQUESTRATION POTENTIAL OF A REGENERATIVE TRANSITION

All of the practices outlined in this chapter have real potential to increase carbon stocks in the UK. The key question, is by how much?

Globally, modelling exercises have come to differing conclusions on the sequestration potential of grasslands, ranging from as little as 150 million tonnes of CO_2 per year (equivalent to approximately 6% of global ruminant GHG emissions) to more than 3.4 billion tonnes (closer to 60% of global ruminant emissions).[96] The Intergovernmental Panel on Climate Change (IPCC) have estimated 1 billion tonnes of potential, which sits somewhere towards the middle of this range, equivalent to around 18% of total current ruminant emissions.[111] There is, however, a lot of uncertainty in these figures, a reflection of the limits of the evidence base gathered to date.

In the UK, even less modelling work has been carried out into the nationwide carbon sequestration potential of improved grassland management. However, a recent review of the climate impact of different grassland and grazing management practices provides a range of estimates.[2] Using data from a number of relevant field studies, the authors modelled the potential contributions to carbon sequestration of a range of different interventions, including rotational grazing, use of legumes and more diverse pastures, were they to be applied to 20% of the UK's improved pasture area (some 1.07 million hectares). The numbers modelled are significant: rotational grazing, for instance, was estimated to sequester around 14 million tonnes of CO_2 per year over the first decade, if it were implemented on this area, while forage legumes were modelled to offer around 10 million tonnes of CO_2e sequestration potential over the same timeframe – equivalent to around 50% and 34% of total UK livestock emissions respectively.

> " A nationwide transition to biologically based farming systems could make a major contribution to reducing UK agriculture's climate impact."

Now, these two figures come with considerable uncertainty – a caveat that, again, points to the urgent need for more research in this area – and they cannot simply be added together, as this would risk double counting. It's also important to note that these sequestration rates were modelled to decline in later years as soils approached saturation, as indicated in Table 3. Still, **these are significant numbers, that, when combined with the potential offered by other practices explored in this chapter (see Table 3), suggest that a nationwide transition to biologically based farming systems, with grazing animals at their core, could make a major contribution to reducing UK agriculture's climate impact over the coming decades**. Critically, such a shift could deliver a host of other key benefits, and this wider perspective needs to be taken whenever the sequestration potential of any management decision is being discussed, to avoid the risk of 'carbon tunnel vision'.

TABLE 3: CARBON SEQUESTRATION POTENTIAL OF REGENERATIVE RUMINANT SYSTEMS IN THE UK

Practice	Sequestration potential (million tonnes CO_2 per year)	Time frame (years)	As a percentage of GHG emissions from UK livestock[6]
Rotational grazing*	c 8.8	25	c.30%
Temporary leys**	2.2-10.6	30	c.8-36%
Agroforestry†	6.1-14.2	30-40	c.21-49%

While there is uncertainty around, and more research needed into, the amount of carbon regenerative practices can sequester, the figures outlined above, taken from published sources, demonstrate that there is real potential to sequester meaningful amounts of carbon in ways that would deliver a host of other benefits.

* Assumes rotational grazing is implemented on 20% of the UK's improved pasture area. The figure of 8.8 million is a weighted average of the sequestration potential for the first 10 years after implementation and the following 15 years.[10]

** Assumes the introduction of temporary leys in arable rotations across the whole of Great Britain's arable area[11]

† Assumes silvopasture on 10% of the UK's grassland area, a 40% expansion in the length of hedgerows in grasslands and the use of 10-30% of hedgerows for woodchip production for biofuel.[12]

Agroforestry, Perthshire

CASE STUDY

Yatesbury House Farm

Richard Gantlett

Richard Gantlett is an organic and biodynamic farmer, with a herd of around 350 Aberdeen Angus beef cattle (130 cows) incorporated into a rotational mixed farming system, along with cultivated crops, including wheat, barley, rye and oats.

The cattle graze on diverse herbal leys, containing up to 29 species of plants, including herbs, grasses and forage legumes. These provide nectar for wild pollinating insects as well as the bees that provide honey for the farm. Richard has also embraced a 'forest farm' approach to silvopasture, allowing his cattle to graze 64 acres of native woodland, which provides shelter from sun and rain and enables the browsing of trees and shrubs. In return, grazing by the cattle increases the plant variety under the trees. The whole farm supports an abundance of species, from bluebells and orchids to hares, tree sparrows, corn buntings, quail and short-eared owls.

One of the most important goals for Richard is for Yatesbury House Farm to become a "zero fossil fuel farm" and he continues to find ways to work with electric vehicles as well as generating and storing electricity on the farm.

Richard conducts regular soil sampling which has clearly quantified the benefits of introducing herbal leys into arable rotations. A scientific study carried out on the farm found that over a five-year period, soil organic matter in the top 10cm of soil increased by between 2.12% and 1.59% each year. This is nearly four times faster than the global target of 0.4% per year suggested at COP21. In 2019, a Farm Carbon Toolkit audit found that the farm was sequestering 10 times more carbon than it was emitting.

While this carbon balance is extremely positive, it was not initially a farm goal. Increasing the life in the soil, by growing diverse leys and grazing cattle, has been the route to carbon storing, nutrient cycling and water absorbtion.

FARM TYPE

Organic/biodynamic mixed beef and arable

LOCATION

Wiltshire

SIZE

1,663 acres

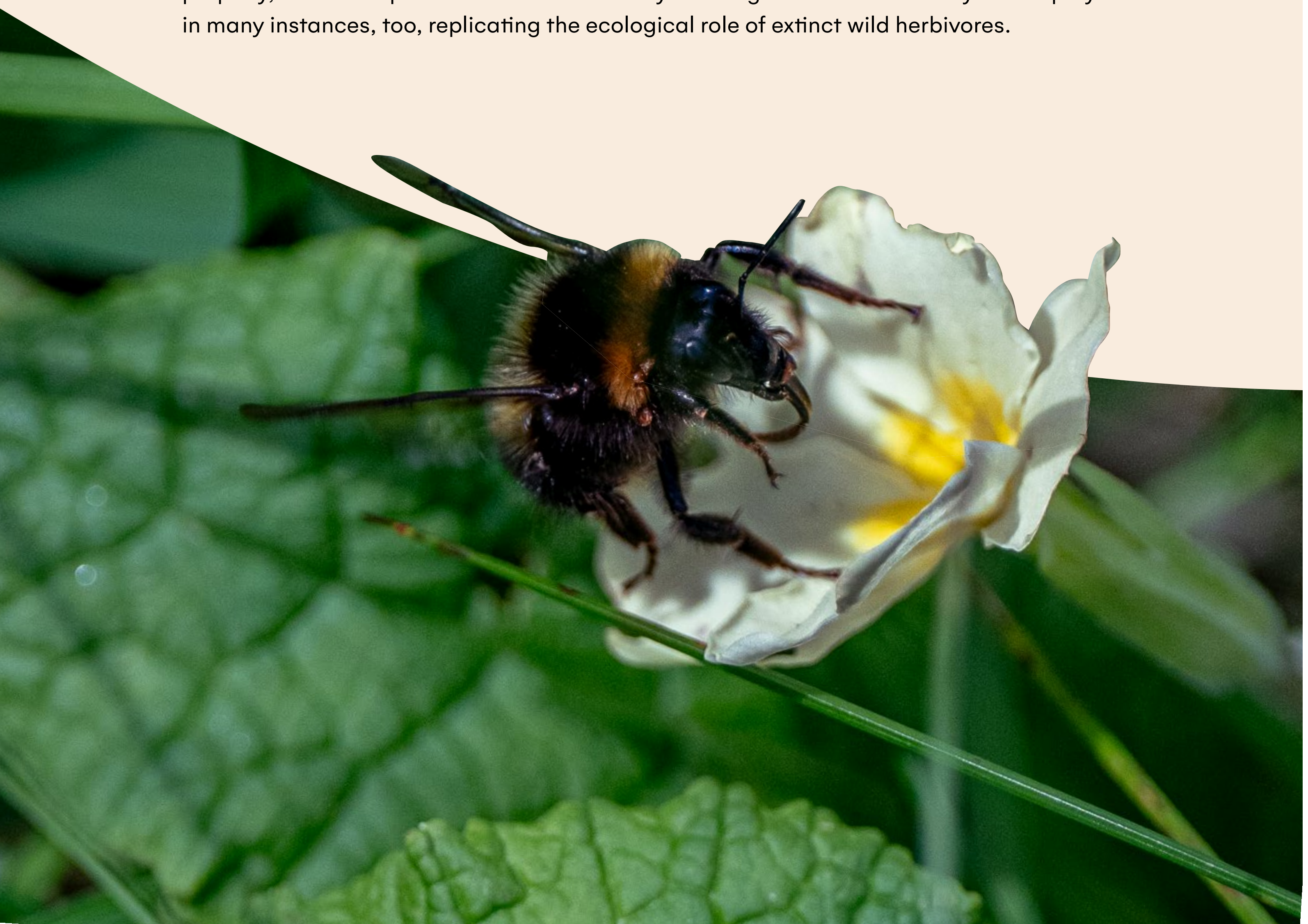
- 685 acres cropping
- 897 acres leys and stewardship

"Our cattle are pasture-fed, and they make an essential contribution to the sequestration of carbon in our soil, the levels of which have approximately doubled since we converted to organic methods."
Richard Gantlett

1.4 Biodiversity

Summary:

- A nationwide transition to low-input, pasture-based grazing systems would help reverse the massive loss of biodiversity caused by decades of intensification.
- On improved pastures and arable land, this shift would foster an increase in farmland diversity, and reduce pollution from intensive livestock production and agrochemical use.
- Grazing is also critically important for some of the UK's most valuable semi-natural habitats, including grass- and heathlands. While many of these are currently in a poor state due to overgrazing, undergrazing has also become a serious problem. Supporting farmers to manage the right types of livestock (including native breeds), in the right way, is, therefore, a key conservation priority.
- Dedicating some farmland for woodland expansion or 'rewilding' projects would, if done properly, deliver major benefits for biodiversity. Grazing livestock have a key role to play here in many instances, too, replicating the ecological role of extinct wild herbivores.



Humanity's impact on the natural world has now become so severe, some scientists are worried we are precipitating the planet's Sixth Mass Extinction. Twenty-five percent of all known species on earth are currently at risk of becoming extinct, while in Great Britain, 1188 species – almost a sixth of the total – are on the IUCN extinction red list.[181]

There are many factors behind this, but the biggest driver of biodiversity loss by far, in the UK and globally, is farming – both through the conversion of natural habitat to farmland, and the degradation and pollution associated with the intensification of agriculture.

While almost every part of the food system holds a share of the blame, ruminant livestock have come in for particular criticism – including in the UK. There are legitimate reasons for this. As discussed in Box 1, an emphasis on maximising production since the Second World War has led to the major intensification of grassland and ruminant production. On better land, this has been characterised by a shift to species-poor, ryegrass-dominated pastures, reliant on nitrogen fertilisers, which now make up around half of all permanent grassland in the UK.[182, 183] While this has driven a major increase in livestock productivity, the effect on nature has been disastrous: only 3% of lowland semi-natural grasslands now remain, and grassland-dominated areas in England and Wales have witnessed huge declines in farmland bird numbers, greater even than those observed in arable regions.[183, 184]

The intensification of ruminant production has also had negative impacts for biodiversity outside of grasslands, through nitrogen pollution on sensitive habitats (see Chapter 2.3), and from the harm caused by agrochemicals used to grow arable feed crops. In the uplands, meanwhile, a sharp increase in sheep numbers over the second half of the 20th century resulted in severe habitat degradation,[185] whilst ruminant production more generally is often seen to be a major barrier to native woodland expansion – though the influence of deer and field sports is often underplayed in this consideration.[xiii]

There is no doubt, then, that too many of the UK's ruminant livestock are being reared in ways that are harmful to nature – but this does not have to be the case. This chapter will look at some of the ways in which well-managed grasslands and grazing animals can play a central role in supporting nature recovery in the UK: by increasing diversity across our farmed landscapes (both within the field and 'around the margins'), by reducing pollution impacts on sensitive habitats, and by managing the many protected habitats and species which benefit, or even rely upon, grazing by herbivores.

Before exploring these benefits, though, it needs to be recognised that some have argued that *all* livestock grazing is inherently bad for biodiversity.[186] This is a claim often based upon a recent meta-analysis, which found that across the globe, the abundance and diversity of almost every group of animals

xiii While much of the uplands is under agricultural use (i.e. rough grazing), often as tenanted land, the owner's primary interest is often in field sports.

was higher when grazing was excluded,[187] findings that have been used to argue that it would be best to get rid of all grazing livestock and allow habitats to revert to their 'natural' state.[186] In reality, the situation is far more nuanced. As the authors themselves recognise, the study mentioned above did not take into account grazing intensity, which, along with the species of grazing animal, their management and the unique context and history of the land, has a major bearing on the impacts that grazing animals will have on biodiversity.[188] For instance, another global meta-analysis that did take grazing intensity into account found that, on average, plant, insect and microbe species diversity increased at light and moderate grazing intensities, but fell under higher, grazing pressures.

In short, context is key when it comes to the relationship between grazing livestock and biodiversity.

RESTORING FARMLAND BIODIVERSITY

The importance of farmland for nature

Since farming arrived on British shores six thousand years ago, humans have shaped almost every aspect of our islands' biodiversity. There is an understandable tendency to think this influence has been overwhelmingly negative, given the loss of much of our native woodland cover, the extinction of enigmatic species like the lynx and beaver, and more recently, the loss of diversity caused by intensification. But agriculture has also shaped our environment in much more positive ways, to the extent that a lot of our biodiversity today actually benefits from traditional farming.

Today, close to half of the UK's most important habitats are found on low-intensity farmland,[190] and many of the UK's most treasured species, from lapwings and skylarks to hedgehogs, bats and barn owls, thrive (or rather, used to thrive) in farmed habitats.[191] These species tend to do well in a 'mosaic' landscape – a mixture of open grassland, arable land, rough field margins, hedgerows, woody areas and ponds – which was once the norm across much of the UK. Each habitat within the mosaic meets a different need, providing food, shelter and breeding sites at various times of the year. Lapwings, for example, will lay their eggs among spring-sown crops before bringing their chicks into adjacent grasslands to feed on insects and worms. Bumblebees, meanwhile, move between hay meadows, clover-rich leys, field margins and hedgerows to forage for pollen and nectar throughout the spring and summer.[191]

Over the last century, however, **the separation and intensification of grassland and arable production has driven a major decline in farmland diversity at every scale – from the soil to the landscape.[192, 193]** Bringing back all that has been lost may not be possible, given the greater demands placed on our farmland by a larger population. Still, there is real scope to reverse much of the damage done. This is an urgent task, not just because farmland biodiversity is of invaluable importance in its own right, but because it also provides critical ecosystem services that underpin our ability to produce food: from pollination and pest control to soil health and water storage.[194]

Many changes to farming practice will be needed if this is to be achieved, but perhaps the two most important objectives are a reduction in nitrogen-intensive inputs, and a greater focus on diversity – be that in terms of the number of habitats on-farm, or the number of different crops grown and species found within fields. Well-managed ruminants can play a key role in delivering on all these fronts – not just in improved pastures, but also in arable-dominated landscapes.

> "The separation and intensification of grassland and arable production, and the consequent loss of traditional mixed farming systems has represented one of the biggest drivers of biodiversity loss in the UK over the last century."

Restoring nature by introducing leys into arable rotations

On arable land, grazing livestock can support significant improvements in biodiversity through their integration – particularly alongside fertility-building leys – into crop rotations (see Chapter 1.1). **One of the major biodiversity benefits that leys offer is a major reduction, or even elimination, in agrochemical use.** Since the publication of Rachel Carson's 'Silent Spring' in 1962, evidence has continued to stack up around the destructive impact these inputs have on biodiversity.[195] Pesticides, herbicides and synthetic fertilisers have been consistently and directly linked to declines in many species, from soil microorganisms and plants, right up the food chain to birds and mammals.[11, 196, 197] In the UK, numbers of flying insects and farmland birds have declined by 60% since 2004 and 1970 respectively, with pesticide use cited as a key driver in both cases.[9, 10]

Introducing temporary leys – especially multi-species ones – into continuous arable rotations has also been shown to deliver

major improvements in soil biodiversity. For instance, a long-term Dutch study found that moving from continuous cultivation to a rotation containing three-year grass leys resulted in a significant increase in soil life, to the extent that various functions typical of a healthy permanent grassland soil biota were delivered.[198] When grazed by livestock, the benefits of leys for soil biodiversity can be even greater, with increases in soil microbes, fungi and earthworms all having been observed (though this is an area that requires more study).[27]

There has been relatively little research into the direct above-ground biodiversity benefits of temporary leys. However, the results of studies that have investigated the biodiversity impacts of organic cropping are relevant here, given that leys containing forage legumes, generally grazed by livestock, are a key feature of organic cropping systems. The findings are significant: across Europe, plant species diversity is 20-95% greater, and plant abundance 150% greater on organic arable farms compared with conventional ones, while total insect species and pollinator numbers are 23% and 30% higher, respectively.[199]

Forage legumes are a key reason leys deliver these biodiversity benefits, in part because they fix nitrogen, but also because they tend to flower at a time of year when most other species found on farmland have finished flowering. For instance, one study found that fields containing forage legumes supported more red-tailed bumblebees and common carder bees than regular grasslands, even those rich in wildflowers.[200] Another, meanwhile, found that skylarks – one of the UK's most iconic farmland birds – were twice as abundant in legume-rich grasslands compared to regular grassland or arable land.[201]

Now, it is important to recognise that a major expansion of temporary leys across the UK's arable area could come at a cost to biodiversity in other regions of the world, if the reduction in domestic crop production this would likely entail were to result in an increase in our overseas agricultural footprint. However, by reducing the amount of cereals fed to livestock, minimising food waste and adopting healthier diets, there is scope to introduce leys at scale without necessitating an increase in imports.

Increasing biodiversity on improved pasture

A move to lower input ruminant systems could also deliver major biodiversity gains across the UK's improved pasture area.[xiv] For instance, a recent study which looked at grasslands managed under 'Pasture for Life' standards – an approach centred around 100% forage-based diets, minimal use of agrochemicals, and rotational grazing – found that they had significantly greater plant species richness than conventional improved pastures.[147] Pasture for Life farms were also found to have taller vegetation, which is known to be important for many invertebrate and vertebrate species.[202] This is particularly true when a mix of different sward heights is maintained – something that rotational grazing systems, the avoidance of overly-high stocking rates and grazing by cattle can all help deliver.[141, 203-205]

Even greater differences in biodiversity were observed in a recent study in southwest England, into the long-term impacts of nitrogen application on grasslands.[206] In swards with a high proportion of legumes but no nitrogen inputs, the abundance and species richness of pollinators and flowers were found to be several times greater than in grass-only plots receiving a standard rate

xiv A nationwide shift from intensive to lower input ruminant systems could also deliver major benefits for biodiversity off-farm, through a reduction in nitrogen pollution on sensitive habitats. This is a crucial point, highlighted in Box 16.

of synthetic nitrogen. Forage yields were 20% lower in the legume-rich, no-nitrogen plots – a finding that, again, highlights why government support will often be needed to enable the shift to more multi-functional, regenerative farming practices. It is, however, important to note that other studies have found that pastures containing forage legumes can equal or even outperform the productivity of conventionally managed swards at much lower levels of nitrogen use,[207] especially when accompanied by rotational grazing.[3]

A more biological approach to the management of improved pastures would also provide biodiversity benefits through reduced reliance on anti-parasitic medication. In set stocking systems, where livestock remain on the same area of grassland for long periods, parasites such as stomach or lung worms and their eggs can build up over time.[208] These systems have become heavily reliant on anti-parasite drugs (or anthelmintics), such as ivermectin, to control worms.[209] The over-use and mis-use of these drugs has led to a growing problem of resistance, but also causes huge harm to a large variety of dung-dwelling invertebrates, including dung beetles.[210] This has impacts across the whole ecosystem, from the farmland birds and bats which feed on dung beetles, to the soil organisms that depend upon the nutrients they recycle into the soil.[211]

A shift to more extensive, rotational systems can help reduce the need for anthelmintics, in various ways. Having periods of no grazing and using a mix of cattle and sheep acts to lower the density of parasites, while there is also evidence that more diverse swards and willow trees contain compounds that help control worm burdens. Carrying out these practices more widely would likely deliver significant benefits for biodiversity, but could also benefit farm profitability. Even today, dung beetles alone save the UK cattle industry £367 million per year on fertiliser and parasiticides, thanks to their disruption of parasite lifecycles and their integration of nutrient-rich manure into the soil.[212]

BOX 9

Hedgerows and farmland trees

Hedgerows were first used for containing livestock and providing them with shelter in the Bronze age. They continue to provide this important function today, with the protection they offer from the sun, wind and rain increasingly relevant in a changing climate.[213] Hedgerows and farmland trees also bring important benefits for biodiversity, providing vital habitats, food and movement corridors for more than 600 plant species, 1500 insects, 65 birds and 20 mammals.[214] These include some of the UK's most treasured species, like the hedgehog, dormouse, bats and bumblebees.[215]

Woody and grassland habitats are often intrinsically linked to one another, each serving different yet interconnected purposes for the species that inhabit them.[172] Pipistrelle bats and farmland birds like the song thrush will nest in the safety of hedgerows and trees, emerging to hunt for worms and invertebrates brought to the surface by livestock grazing in adjacent pastures.[216] The greater horseshoe bat, yellow-necked mouse and field vole have all been found to thrive in greater numbers when their hedgerow homes are close to semi-natural grassland.[217, 218] Unfortunately, UK hedgerows are in a poor state, particularly in arable areas – largely, because they were often seen as serving little to no purpose in intensive cropping systems. Improving the condition and extent of hedgerows would, therefore, deliver major benefits, including for biodiversity and carbon (as discussed in Chapter 1.3).

Silvopasture – a different form of agroforestry, where trees and livestock are grown on the same piece of land – can also deliver major biodiversity benefits, alongside those for carbon discussed in Chapter 1.3.[170] Studies have often found that fields containing trees support a greater diversity of plants, insects and small mammals than conventional pasture or arable fields.[219] This is hardly surprising, as open 'wood pasture', which used to cover a much greater proportion of the UK, can support incredibly high levels of biodiversity. This is in large part because more light is allowed through the canopy than dense forest, helping a mixture of both grassland and woodland species to survive.[219, 220]

Biodiversity on pastures

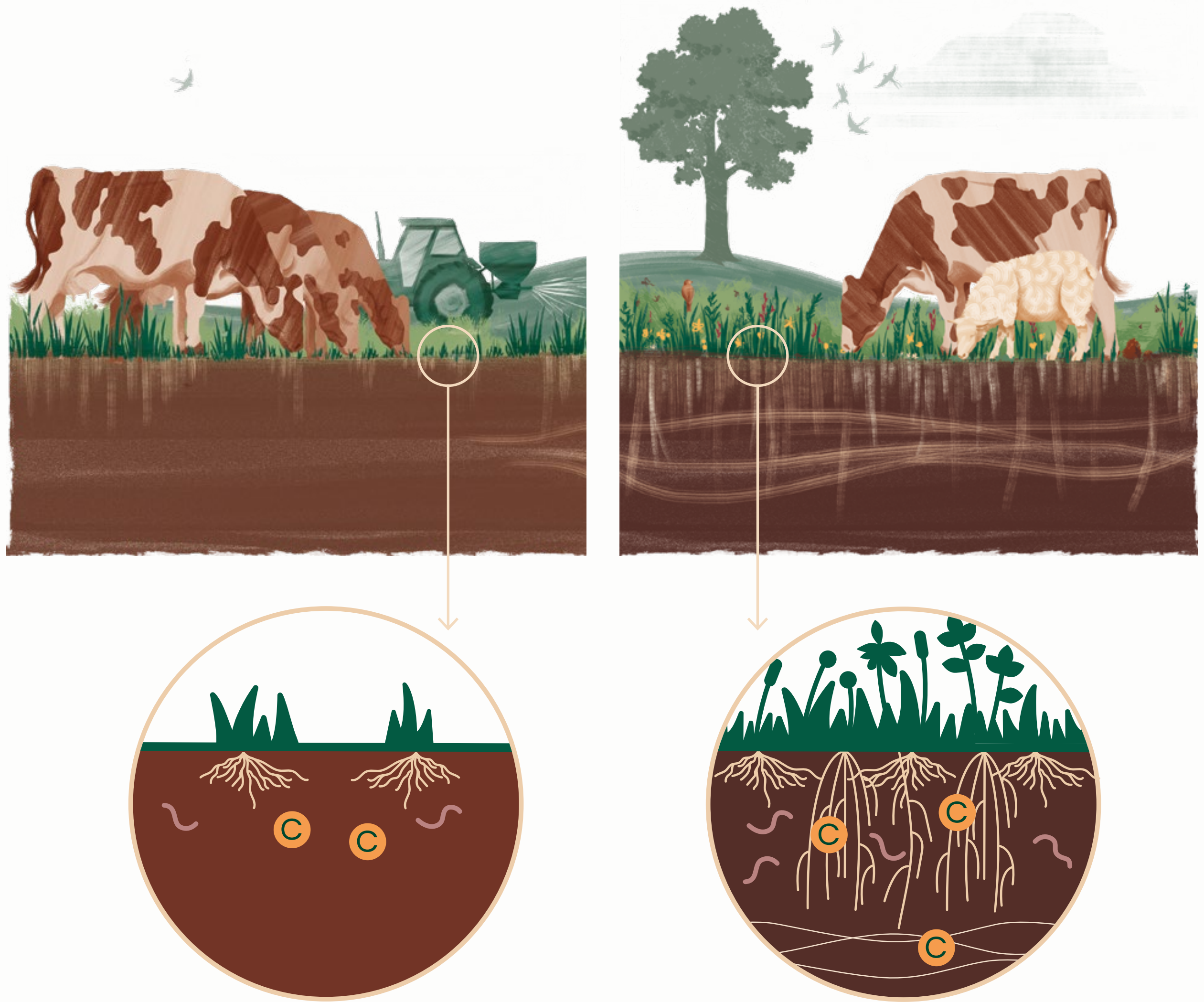
Intensive vs regenerative grazing

Intensive

Many of the UK's pastures are highly productive but species-poor, receiving often large amounts of nitrogen from synthetic fertilisers and slurry. This approach results in low levels of grassland biodiversity, and is a major contributor to nitrogen pollution in protected habitats.

Regenerative

Regeneratively-managed pastures contain forage legumes, which fix nitrogen and minimise the need for synthetic fertilisers. This, alongside the use of rotational grazing practices, promotes greater plant diversity, which supports wider grassland biodiversity and reduces nitrogen pollution – benefits strengthened by the integration of trees and livestock.



KEY: C Carbon

THE IMPORTANCE OF GRAZING FOR SEMI-NATURAL HABITATS

One of the most important yet underappreciated services provided by grazing livestock is their critical role in maintaining many of the UK's most important semi-natural habitats.

Semi-natural habitats, including grasslands, heathlands and moorlands, are a key feature of landscapes across Europe, and have been shaped – and in many cases created – by farming over thousands of years. As a result, they depend on some form of human intervention, either grazing, mowing or burning, to maintain their open nature and prevent the encroachment of scrub and woodland.

As well as being culturally cherished components of the landscape, semi-natural open ground habitats are critically important for biodiversity – a reflection of the fact that prior to the arrival of humans, more than half of Europe was open or lightly wooded.[221] Fifty percent of Europe's native plant species are found in grasslands,[222] while in the UK, at least 42 endangered species of bird require lowland semi-natural grasslands at some stage of their lifecycle.[223] Grazing livestock play a vital role in managing these areas, helping create and maintain the open vegetation structure on which this biodiversity depends. Across Europe, more than 60 habitats of conservation importance have been shown to benefit from, or even rely upon, traditional farming practices, the most important being grazing.[224] It is for this reason that grazing livestock are a common sight on nature reserves and a key tool in the 'conservation grazing' management of grasslands and other open-ground habitats, such as wetlands (see Box 10 for some specific examples). Grazing livestock can even play a positive role in improving the species and structural diversity of native woodlands, reflecting the key ecological role large herbivores play in many wooded habitats, too.[225]


Purple moor grass and rush pasture


Upland calcareous grassland


Grazing marsh


Hay meadow

BOX 10

Examples of protected habitats that rely on grazing

While the conservation value of grasslands has often been overlooked, they are a crucial part of the UK's ecological and cultural heritage. Some of our most important protected habitats are outlined below:

Purple moor grass and rush pasture

Known by various names, including culm grassland in Devon and rhôs pasture in Wales, this habitat is found on wet soils, mainly in Western parts of the UK. Generally characterised by a tussocky cover of purple moor grass and sharp-flowered rush, it can contain a wide variety of species-rich plant communities, and is an important habitat for many species of conservation concern, including the marsh fritillary butterfly and snipe. Grazing plays a key role in maintaining the structurally diverse sward many plant and invertebrate species need to thrive, something that hardy native cattle breeds, like Ruby Red Devons, are perfectly suited to deliver.

Upland calcareous grassland

Found on upland lime-rich soils, these grasslands cover less than 20,000 hectares in the UK but support some of our most precious plant communities, including rare arctic-alpine plants like the alpine mouse-ear and alpine cinquefoil. While many areas are currently overgrazed by sheep, light grazing is essential as without it plant litter can build up, which alters the pH of the soil and allows more competitive species to replace rarer plants.

Grazing marsh

Grazing marsh is a seasonally-flooded habitat, found mainly in low-lying parts of England. While it can support high levels of plant and invertebrate diversity, particularly in and around ditches, it is the populations of breeding waders and internationally important numbers of wintering wildfowl that are the most valuable features of this habitat. Low level grazing, especially by cattle over the summer months, helps maintain a diverse vegetation structure, and provides the supply of dung needed for many invertebrates.

Lowland and Upland meadows

Unimproved neutral grasslands – generally classified as either Lowland or Upland Hay Meadow – were once a near-ubiquitous feature of farms across the country, but decades of intensification have reduced them to a fraction of their former extent. Those that remain, however, tend to be incredibly diverse, supporting a wide variety of special plants (including green-winged orchid in the lowlands, and great burnet in the uplands) as well as endangered birds, like the corncrake and twite. Hay meadows are usually grazed in the winter and cut for hay in the summer, a traditional approach to management that provides the disturbance needed to maintain habitat diversity.

Over- and under-grazing in the uplands

Many areas of semi-natural habitat have been converted to intensive farmland over the past century, particularly in the lowlands, where only fragments now remain. Much more extensive areas are still found in the uplands, but even though these are often now protected and included within agri-environmental schemes, many are in a poor condition.[227]

One of the main reasons for this was the major increase in sheep numbers that occurred through the 20th century, a trend that caused serious degradation, through a loss of species diversity and a shift from dwarf shrub and mixed vegetation communities to grasslands dominated by a handful of species.[228] In recent decades, the decline in sheep numbers seen in many upland areas, brought about by Foot and Mouth disease and a change in European agricultural policy, has allowed for something of an improvement in the ecological condition of certain habitats, such as wet and dry heaths and blanket bogs.[229] However, **the ongoing loss of livestock from the hills has also seen undergrazing becoming an increasingly serious threat.** Undergrazing has been a major conservation concern in Europe for some time, and in the UK now presents a growing problem both in the uplands and on the fragments of semi-natural grasslands which survive in the lowlands.[229]

The loss of hill cattle, as a consequence of the ongoing lack of profitability of hill farming and the longer-term shift from mixed cattle and sheep to sheep-only systems, is a particular concern, as it appears to have contributed to declining species diversity in at least some habitats.[229] For instance, studies have found that ungrazed grasslands have lower densities of breeding waders,[230] and that bird and butterfly species diversity is higher when vegetation is grazed by both cattle and sheep, rather than by sheep alone.[231] The loss of hill cattle has also been implicated in the steady encroachment of purple moor grass (often known by its genus name, Molinia), and bracken, across many areas, the outcome of which is often a loss of species and habitat diversity.

Reduced levels of grazing in the uplands pose a threat for soil biodiversity, too. A recent study of upland sites across the UK, for example, found that in plots where grazing was removed,[232] soil microorganism diversity was significantly reduced, particularly for rarer species. Plant species diversity was also found to be 30% lower than in grazed plots.

> "studies have found that ungrazed grasslands have lower densities of breeding waders, and that bird and butterfly species diversity is higher when vegetation is grazed by both cattle and sheep, rather than by sheep alone"

Ensuring the long-term viability of extensive livestock farms is, therefore, not just a key priority from a social and cultural perspective, but also an ecological one. This is something that previous government policies have often failed to deliver. However, as the Burren LIFE programme in south west Ireland has shown, agri-environment schemes that are co-designed by farmers and ecologists, and which are results-based, can deliver major improvements for biodiversity and rural communities.

BOX 11

Dartmoor – a contentious case study

Dartmoor is in many ways a microcosm of the current debate around the role of grazing livestock in the UK's uplands. It is an iconic landscape, shaped by millennia of human activity and cherished for its aesthetic, cultural and ecological value. Over recent times, however, the moor has become seriously degraded, with most of its habitats now in a poor condition, and many protected species on the brink of extinction. The precise causes of this continue to be debated, but while peatland drainage and cutting, nitrogen deposition and burning have all played significant parts, overgrazing, particularly during the late 20th century, has undoubtedly been a major contributor, too.[223]

Millions of pounds of public money, spent through decades of agri-environment schemes, have failed to deliver any meaningful improvement in the condition of the moor, and this has led to calls for further reductions in livestock numbers. These recommendations, unsurprisingly, have been met with fierce opposition from a farming community that is already struggling under the weight of an uncertain future, and this has precipitated a massive, often toxic argument over the future of the moor.

In response to this, Defra commissioned an independent review into the management of Dartmoor's protected sites. Acknowledging the complex nature of the challenges being faced, the review noted that the moor's problem is not just one of overgrazing, but also, in many instances, undergrazing.[233] While reducing the number of grazing animals will, therefore, be necessary in some areas and at certain times of the year, supporting well-managed mixed grazing systems with cattle, ponies and sheep will also be critical, especially in areas where aggressive species like gorse, bracken and in particular Molinia need controlling.

To realise this more positive future, genuine collaboration between all stakeholders will be needed – something that the development of landscape recovery areas and a land use management group should help deliver. This will require an acceptance within the farming community that things need to change. But it will also require a change in approach from government and its statutory bodies, including properly funded support schemes that help farmers make the necessary changes in management practice – something that many would argue, has not been delivered to date.[234]

GRASSLAND AND NATIVE WOODLAND: NOT AN EITHER/OR

Grazing animals clearly play an essential role in the maintenance of many semi-natural habitats. Some, however, have argued that even well-managed cattle and sheep farms come with a significant 'opportunity cost' for biodiversity: firstly, because they prevent native woodland re-establishment, and secondly, because farmed animals do not provide the full range of ecological functions that wild herbivores would within a rewilding scenario.

Rewilding involves the landscape-scale restoration of the full (or near enough full) suite of natural processes and species that would be present were it not for human activity. In a UK context, this is generally taken to mean the restoration of native woodlands and shrubland, and the extinct species that inhabited them, including large herbivores, like wild cattle and horses, and, more controversially, extinct predators like the wolf and lynx.[235]

The debate around reforestation and rewilding is complex, and to do it justice requires more space than is available here. In short, though, there is no doubt that the UK's biodiversity would benefit hugely from an increase in woodland cover – a shift that could deliver significant carbon gains too. But this does not have to be an either/or decision. Modelling shows that the UK could achieve a significant expansion of native woodland, and 'wilder' land more generally, whilst maintaining grazing livestock as a key component of the food system, providing we also change our diets and reduce food waste.[32]

That said, there are risks and limits associated with woodland expansion – as there are with any land use change – and these need to be recognised. One of these is the threat that woodland expansion can pose to open-ground biodiversity. While conifer plantations can provide benefits for nature, including where non-native tree species are grown,[236] they can also have a negative impact, especially when established on semi-natural habitats.[237] This threat can even apply to native woodland, both where trees have been planted, and where natural regeneration of scrub and trees has occurred due to a lack of grazing.[237]

In response to this, it is sometimes argued that converting, say, an area of moorland to native woodland will generally result in an overall gain in biodiversity, given the higher number of species that the latter habitat often supports.[238] This, however, is an over-simplification. For a start, it ignores the possibility that an open-ground habitat, whilst lower in overall species diversity, may support species of greater conservation concern – ground-nesting waders being a commonly-used example.[223] Open-ground and woodland habitats also have very different assemblages of species. Ancient woodland, for instance, tends to have the highest overall levels of plant species richness, and is particularly important for mosses, lichens and liverworts, whilst open-ground habitats often support higher levels of diversity among other groups, such as flowering plants.[239]

The importance of habitat diversity

None of this is to say that the conversion of grassland to woodland or scrub is necessarily a bad thing for nature – in landscapes where most native tree cover has been lost due to human activity, the opposite will likely be true. This raises a key point, which is that having a wide diversity of habitat types is crucial to biodiversity. Context-specific decision-making, rather than a blanket shift to new forms of land use, are needed to realise this.

As previously mentioned, it could be argued that rewilding offers the best means of delivering this diversity of habitat types, with the ecological benefits of grazing instead provided by wild herbivores.

Semi-natural grassland, Dorset

Rewilding projects have certainly delivered major benefits for biodiversity, including for species that rely upon or benefit from grazing, as seen for example at the Knepp Estate.[240] It is also clear that rewilding can deliver real social and economic benefits (see Chapter 1.5).

There are, however, legitimate concerns around the way in which landscape-scale nature restoration projects are sometimes delivered, and various reasons as to why there are limits to the extent to which rewilding can or should replace hill farming. These include concerns around livelihoods and social justice, and the potential loss of social and cultural services provided by hill farming and grazing animals – including, of course, food provision (see Chapter 1.5). In a densely populated country like the UK, there are also likely to be public concerns over the risks to safety (perceived and real) of wild herbivores.[241] There can even be threats to biodiversity, especially where 'rewilding' simply constitutes the removal of human intervention, and no efforts are made to ensure the restoration of all natural ecological processes – including, of course, grazing by large herbivores.[242]

Many rewilding advocates recognise these issues, and none of this should detract from the fact that rewilding could play an important role in enhancing biodiversity in the UK. There is both the need and the space for a degree of 'wilding' in many landscapes – not just on agricultural land, but also on that used for shooting and commercial forestry. In some cases, this could occur in a fairly 'pure' form, with little to no agricultural activity – though this would obviously need the support of those living and working on the land. However, given the concerns and limitations highlighted above, there may be greater scope for rewilding to be delivered in tandem with livestock farming. This could occur across a spectrum of intensity of human intervention, from agroecological farms with a strong emphasis on encouraging natural processes, to wilder landscapes that might fall under the terms 'agricultural rewilding' or 'rewilding-lite'.[243] In all of these scenarios, grazing livestock, particularly native breeds (see Box 12) will play an essential ecological role.

BOX 12

The value of native livestock breeds

Native breeds of cattle and sheep have a vital role to play in the management and restoration of many habitats. While the way in which they graze may not differ substantially from Continental breeds, traditional, local breeds tend to be hardier, making them well-suited to the local terrain.[244] Their ability to live outside in harsh conditions, thrive on rough vegetation without large quantities of supplementary feed and greater resistance to diseases, means native breeds are hugely valuable for farmers operating low-input systems.[231] They also represent an important genetic resource, particularly in the face of climate change, while the fact that many breeds are smaller in size than conventional breeds makes them less likely to cause poaching – the exposure and compaction of soil – on wet ground.[245]

Sadly, many of the UK's native breeds, along with their genetic diversity and unique cultural value, are at risk of being lost.[246] The Rare Breeds Survival Trust (RBST) has identified key priorities to ensuring their survival.[247] These include increasing support for small, local abattoirs, which can process fewer and more varied animals and revising the carcase grading system – which is currently focussed on meat yield and fat content and does not account for other features, such as eating quality and taste, key selling points. Addressing these issues would help farmers to preserve the UK's native breeds, and the biodiversity benefits they can deliver.

Native breed, Belted Galloway

1.5 Rural communities and landscapes

Summary:

- Cattle and sheep farming are a key source of rural livelihoods, and form an integral part of the social and cultural fabric of many communities, particularly in some of the UK's most environmentally and economically constrained regions.
- Grasslands and grazing animals also provide broader cultural benefits, helping to maintain cherished pastoral landscapes that hold high aesthetic and recreational value.
- Transitioning to a biologically based, more localised food system could further strengthen these social and cultural benefits – for instance, through the creation of livestock-related jobs in arable areas, and improvements in mental wellbeing amongst farmers and the public more broadly.

When it comes to discussions around farming and sustainability, there is a tendency to focus on easily quantifiable issues. What is the impact on carbon footprint? How many calories are yielded per hectare? How many species of bird can be found?

These are obviously key questions, but social and cultural issues – such as aesthetic and recreational value, physical and mental wellbeing and sense of place – are no less important, not least because they are essential in reconnecting people with the natural world.[247] Grasslands and grazing animals have a hugely important role to play in this regard, and while this report only takes a short look at these issues, a few points are worth highlighting.

THE SOCIAL AND CULTURAL VALUE OF GRASSLANDS

The first and perhaps most obvious social benefit provided by grasslands and grazing livestock in the UK is their contribution to the rural economy. Now, it is sometimes argued that farming's economic contribution is actually fairly insignificant – agriculture accounts for less than 1% of the UK's economic output and 'only' 3% of England's workforce.[186] However, this fails to take regional variations into account. In some parts of Scotland, for instance, agriculture provides employment for 12-15% of the workforce – a figure that rises when the number of people employed in associated industries, such as processing and retail, are accounted for.[248] Factor in the high rates of depopulation and deprivation many remote areas suffer from, and it becomes even more apparent that ruminant agriculture has a much more important role to play in the wellbeing of rural communities than national statistics might suggest.[249]

This contribution to the wellbeing of rural communities extends well beyond the provision of jobs. While ruminant agriculture holds a less prominent role in the social and cultural life of rural Britain than it did even 50 years ago – a shift that, as with the loss of farming jobs more generally, has come at a huge cost to rural communities and farmer wellbeing – it is still extremely important. For example, up to 65% of households in parts of the north and west of Scotland are engaged in crofting – a unique system of land tenure and small-scale food production in which grazing livestock are key, and which continues to play a central role in upholding Gaelic language and culture in the Western Isles, as well as the Nordic-influenced culture of the Northern Isles.[250] In Wales, meanwhile, the proportion of Welsh language speakers within the agriculture sector is more than double the national average.[251]

The UK's grazed landscapes also provide cultural benefits for society more generally. For instance, a recent European review of the ecosystem services provided by different land uses found that permanent grasslands deliver, on average, greater aesthetic and recreational value than croplands, temporary grasslands or woodlands.[108] There is also research, from Europe and the UK, which shows that the public value the presence of grazing livestock in the landscape, including when asked to describe their vision of an 'environmentally friendly farm'.[252]

Of course, it can be difficult to measure these less tangible benefits, and landscape preferences vary from person to person. Neither should we let society's landscape ideals blind us to the very real problems facing the UK countryside, many of which have been driven in part by unsustainable livestock management. However, this does not mean that the public's preference for grazed landscapes should be ignored – quite the opposite, in fact.

For a start, research has shown that most people have a strong preference for landscapes and grazing systems which are less intensive, more diverse and which include trees[252] – attributes that, if replicated at scale (and if accompanied by a shift in diets) would deliver enormous benefits for the environment, including for the supply of clean water and flood risk regulation (see Box 13). We also know that aesthetic value, and the sense of place it can help generate, is often as much about human influence in the landscape – with the use of nature-friendly farming practices being a key example – as it is about environmental factors. **If, then, we are to achieve a transformation in land use that has buy-in from the general public, and farmers, there is a strong argument to be made that low input, pasture-based grazing systems have a critical role to play.**

The promises and challenges of alternative land uses

None of this is meant to denigrate the social, cultural and economic contribution of other land-based sectors, of course. Forestry, for example, is an important employer in many areas, and rewilding can generate a variety of rural jobs (alongside positive outcomes for nature, see Chapter 1.4).[253] In many cases, these activities could also offer economic benefits to farmers, as part of a diversified farm business. However, the argument made by some that landscape-scale afforestation could provide alternative sources of employment for the whole grazing livestock sector, is much more problematic.

There are, for instance, social justice concerns around how some nature restoration projects are being carried out today. Although often beneficial from an ecological perspective, the purchasing of large estates in Scotland by wealthy 'green lairds' has helped entrench a concentrated pattern of land ownership.[254, 255] The recent boom in natural capital markets, meanwhile, has contributed to soaring land prices, further limiting the possibility for community land ownership whilst enabling corporations, including oil and weapons firms, to offset their emissions by paying for the carbon credits generated by woodland creation.[256]

The extent to which rewilding can support the same number of land-based jobs as farming across entire regions is also highly questionable, particularly in areas where small and medium-sized family farms remain commonplace. Again, this is not to say that rewilding necessarily represents a threat to rural communities – as outlined already, it can be a huge positive. The point is that a just transition will be much more achievable if a greater number of meaningful jobs are created across a variety of land-based sectors.

IMPROVING WELLBEING

At present, far too many cattle and sheep farmers are failing to make a good living. Isolation, long working hours, a lack of profitability and the drive for more intensive, extractive systems are all taking a terrible toll on the mental health and wellbeing of many farmers.[233] Livestock producers, especially those in remote areas, are more likely to suffer from depression and anxiety than arable or horticulture farmers,[257] whilst intensive livestock systems with poor animal welfare often cause emotional distress for farmers and those involved in the slaughtering and processing of animals.[258]

While there are no simple solutions to these problems, **a move to a more agroecological approach to livestock farming could help.** A wealth of anecdotal evidence, as well as the very limited amount of research carried out to date, shows that such a shift can provide more fulfilling farm livelihoods.[259] It could also generate a significant increase in farm employment – in part, because of the jobs created by reintegrating livestock into arable areas. One study, for example, found that converting 20% of the UK's farms to organic would result in a 19% increase in farm employment.[260] This would bring obvious benefits for rural communities suffering from a lack of jobs and depopulation, but it could also provide more opportunities for 'care farming' or 'green social prescribing', which can deliver real improvements in mental health – particularly when farmed animals are involved.[261] **A transition to pasture-based systems would also, in many cases, support major improvements in animal welfare.**[262]

Achieving this will rely on an expansion of local food systems, which retain a greater portion of revenue in the local economy, and allow farmers to foster more meaningful relationships with the community.[263] Key to this is having a network of **small, local abattoirs**. These provide numerous benefits over industrial scale slaughterhouses, including higher animal welfare through shorter journey and waiting times. Small abattoirs also tend to better accommodate the needs of regenerative producers, who may take only a small number of animals to slaughter at a time, and who often rear native breeds which require additional processing (e.g. large horns).

BOX 13

The role of grasslands in supplying clean water and flood risk regulation

The UK is going to have to adapt to increasingly frequent, and intense, periods of rain and drought – with major implications for how we farm. This is a challenge which biologically based farming systems can play a central role in addressing. A move from all-arable farming to ley-arable systems, for instance, could help increase the genetic, landscape and enterprise diversity of farms, so spreading weather-related risks. Agroforestry expansion, meanwhile, would provide more shade and shelter for crops and livestock.[271] But perhaps the biggest climate adaptation benefit of an agroecological approach to food production is that it tends to increase a farm's water holding capacity, thanks, in particular, to the higher levels of soil organic matter generally found in biologically based systems. This is something which grasslands are key to delivering.

Stable organic matter can absorb several times its own weight in water,[265] just one of the reasons why increasing soil organic matter levels is a crucial objective (see Chapter 1.3). Grassland soils contain much higher levels of organic matter than arable soils, and this means they soak up water much more effectively than arable land, reducing the speed of runoff and the risk of rivers bursting their banks.[264] This is particularly true with semi-natural and extensively managed grasslands, which are far more effective at reducing the risk of flash flooding than those which are over-grazed. Culm grasslands in North Devon, for example, hold more than four times as much water as intensive grassland, and have much slower rates of water runoff, even when the soil is already waterlogged.[267] The integration of trees into grassland has also been shown to dramatically improve water infiltration rates in pastures, significantly slowing the flow of water and helping reduce peak river flows during heavy rain.[272]

Grasslands can play an even more direct role in flood prevention, in the form of floodplain meadows. Clifton Ings and Rawcliffe Meadows, for example, are a crucial part of York's flood defences, with their combined water-storage capacity of approximately 2.3 million cubic metres helping reduce the level of floods by up to 15 cm.[266]

The capacity of grasslands to store huge quantities of water can bring major benefits during periods of drought, too – including in arable rotations that incorporate temporary leys. Grasslands also act as water filtration systems, with semi-natural grasslands being particularly effective at removing harmful pollutants from rainwater. With approximately 70% of the UK's water resource coming from the uplands, upland grasslands are particularly important for maintaining good water quality – key for the supply of drinking water.[268-270]

CASE STUDY

Home Farm

Sophie and Tom Gregory

Sophie and Tom Gregory are first-generation organic dairy farmers. Their focus is on producing nutrient-dense milk from grass – milking a herd of 400 Jersey, Friesian and Shorthorn cows.

They have been farming organically for over 10 years, motivated by animal welfare as well as the economics of the system, but more recently deciding to take a step further in improving soil health by moving towards regenerative principles, including mob grazing, the introduction of diverse herbal leys and reseeding their fields using a direct drill.

Alongside the benefits to the soil and biodiversity that farming regeneratively has brought to the farm, Sophie and Tom are especially dedicated to maximising the social value of farming in this way, something which is much harder to measure. They use Home Farm as an educational platform, regularly hosting visitors, from school children to farming discussion groups, in order to inspire more people to become involved in regenerative farming, especially those from non-farming backgrounds.

> "For us it's a way of looking at the business as a whole and making sure that we are having a positive impact on the people working here, the community, the soil, nature and the herd."
>
> Sophie Gregory

FARM TYPE

Organic dairy

LOCATION

Dorset

SIZE

Approximately 1,400 acres

- 600 rented acres at Home Farm
- 300 rented acres of permanent pasture nearby
- 300 acres of organic arable
- 200 rented acres for Wild Park Cattle grazing as part of a rewilding project

Part 2

Livestock and climate change: the need for reassessment

Part 2 - Summary

For all the benefits outlined in Part 1, grazing livestock are often labelled as the least climate-friendly form of food production, due to their high greenhouse gas and land use footprints. Part 2 explains why this is an overly simplistic characterisation, that overlooks the central role that grazing livestock could play in a UK food system that, through a transition to regenerative farming practices, and a shift to diets containing smaller amounts of high quality meat and dairy, could deliver major benefits for the climate, as well as people and the planet.

2.1 LAND USE: GRAZING LIVESTOCK AND WOODLAND EXPANSION – Looks at how an increase in the UK's tree cover can be delivered as part of a transition to a biologically based food system, where grazing livestock play a key role.

2.2 NITROUS OXIDE: THE FORGOTTEN GREENHOUSE GAS – Summarises how shifting from industrial livestock production to lower-input, pasture-based systems, that rely on forage legumes instead of fertilisers, could reduce emissions of this potent greenhouse gas, as well as other forms of nitrogen pollution.

2.3 THE METHANE DEBATE – Examines how an ongoing though reduced level of ruminant methane emissions is compatible with a net-zero future, and how these reductions might be achieved sustainably.

2.4 MEASURING CLIMATE IMPACT – Highlights the need for a more holistic, whole-system approach to assessing climate impact, which accounts for a broader range of sustainability indicators and outputs.

RUMINANTS AND CLIMATE CHANGE: SETTING THE SCENE

Well-managed grasslands and grazing livestock clearly offer major benefits to society. They help enable more circular, resilient cropping systems that do not rely on synthetic inputs, produce a significant supply of nutrient-dense food from forage, support high levels of biodiversity and deliver a range of social and cultural benefits.

The UK's grazing lands also store huge stocks of carbon, with the potential to build on these through improved grassland management, the reintroduction of livestock into arable rotations, and the reintegration of trees into pasture. For some, though, grazing systems are seen to carry an environmental burden that overshadows the benefits they deliver – their greenhouse gas (GHG) and land-use footprints.

When measured in the conventional manner (see Box 14), the global average carbon footprint of suckler beef is the highest of any food – at 99.48 kg CO_2e per kilogram of product, it is ten times that of chicken (9.87 kg CO_2e) and more than twenty times that of rice (4.45 kg CO_2e). From this perspective, extensive ruminant products tend to have the highest footprint of all – mainly, because animals reared on grass are slower growing or lower yielding than those fed large quantities of grain, and therefore produce more emissions per unit of output.[273]

It is a similar picture when it comes to land-use footprint. When expressed as total land use per kilogram of product – as is generally done today – the land-use footprint of suckler beef is almost thirty times greater than that of chicken and the highest-footprint plant foods, with extensively reared ruminant products once again appearing 'worse', due to the lower average productivity of animals reared on grass.[274] The climate criticism here is that a larger land footprint means less land for alternative land uses, like woodland – and, therefore, less potential for the carbon sequestration that trees can deliver.

BOX 14

A note on carbon footprints

A food's carbon footprint is the total amount of GHG emissions its production (and sometimes transport) adds to the atmosphere. Generally, carbon footprints are expressed per kilogram of food or protein, with the contribution of different gases reported as a single carbon dioxide equivalent (CO_2e) emissions figure. This is usually calculated using a metric called the Global Warming Potential 100 (GWP100), so-called because it assesses the impact of a product's emissions over 100 years.[111]

While standard practice, using GWP100 as the sole means of assessing the climate impact of different foods can be misleading, and improving how we measure the environmental impact of food is a critically important issue (see Chapter 2.5).

Now, because these figures are globally averaged, they obscure the huge amount of variation in footprint size, depending on how and where a food has been produced. There is, for example, a tenfold difference between the top and bottom 10% of beef carbon footprints globally, with the footprint of UK-produced beef just half the global average.[275, 276] This is important, for a number of reasons: it underlines how much scope there is to improve the sustainability of food production in many instances, and highlights the climate risk posed by cutting production in a low footprint region like the UK, only for production to then shift to areas where it is more impactful.

It does not, however, change the fact that the production of a kilogram of beef or lamb generally results in more GHG emissions and requires more land in total than the production of a kilogram of chicken, or pretty much any staple plant food – a fact that holds true both globally, and in the UK.[276]

Given the urgent need to reduce emissions from agriculture and free up land for habitat creation, how, then, can it be argued that grazing livestock have any sort of meaningful role to play within a climate-friendly food system?

This is the question which Part 2 of this report sets out to address, by considering several points:

- Contrary to what is often repeated, biologically based grazing systems in the UK tend to have a similar or even smaller carbon footprint than conventional ruminant systems, even when measured in the standard way.[277] What's more, there should be considerable potential over the coming years to reduce these footprints further (Chapters 2.2 to 2.4).

- We also need to factor in the carbon sequestration potential of a nationwide shift to pasture-based livestock systems, which, as seen in Chapter 1.3, could be hugely significant – something that is often not accounted for in discussions around the climate impact of ruminants.

- The transition to a biologically-based UK food system will involve major changes to livestock production. An important consequence of this move away from industrial, heavily grain-fed systems will be a reduction in the overall amount of animal-source foods we produce and consume – a shift that in itself would significantly reduce emissions and create more space for woodland, both in the UK and overseas.[31-33]

- At the same time, there are various reasons why we do not need or want to spare most of our grazing lands for tree planting (Chapter 2.1), and similarly, why we do not need or want to get rid of all ruminant GHG emissions – the latter point being especially relevant to the key question of how we understand and act on ruminant methane, a gas that is fundamentally different to carbon dioxide (Chapter 2.4).

- Finally, we need to stop judging the sustainability of foods solely on the basis of conventional 'emissions intensity' footprint metrics, like those referenced on the previous page. Instead, the climate impact of grazing livestock, and indeed all farming systems, must be measured in a more holistic manner – not just through a broader range of footprint metrics, but also by looking at the impact of the whole food system, as is explored in the final chapter of this report (Chapter 2.5). Crucially, *this has to be part of a genuinely holistic consideration of all aspects of sustainability, to ensure that we avoid carbon tunnel vision*.

BOX 15

Tackling ruminant emissions through sustainable intensification

To date, much of the discussion around how the ruminant sector might reduce its emissions has focussed on efficiency-improving measures that fit within a 'sustainable intensification' agenda,[278] that is largely concerned with reducing emissions intensities. Some of these measures and practices – for instance, improving animal health, better slurry and manure management, and breeding to reduce emissions – can be adopted very successfully within pasture-based, agroecological systems without compromising their core design principles. Others, however, are more problematic. There have, for instance, been concerns raised about the potential impacts of some nitrification and methane inhibitors on human, animal and environmental health, and most feed additives are at present practicably unsuitable for use in grazing systems because they need to be fed in a mixed ration at least once daily (see page 114 for more on methane inhibitors).

Increasing the proportion of cereals and maize in the diet as a means of reducing carbon footprints through shorter finishing times comes with potential problems too, for animal welfare, feed-food competition and soil health.

There is also no guarantee that a move to lower emission intensity and higher yielding practices will reduce emissions overall, or free up agricultural land – in fact, there is a danger that improved productivity could encourage further increases in production, negating the sustainability benefits of lowered emissions and land-intensive production: a phenomenon termed Jevon's Paradox.[279] Yield per hectare and emissions intensity are still important metrics, of course, but they should not be the sole means by which the sustainability of different food and farming systems are judged. These are issues discussed further in Chapter 2.5.

2.1
Land Use: grazing livestock and woodland expansion

Summary:

- The high land-use footprint of cattle and sheep production in the UK is often seen as a barrier to woodland creation. However, we can create more space for trees whilst maintaining grasslands and grazing livestock as central components of our farmed landscapes. This includes the potential for a much greater integration of trees and livestock, through an increase in the area under hedgerows and wood pasture – the benefits of which are explored in Chapters 1.3 and 1.4.

- While there are also major benefits to be gained from an increase in woodland and forestry cover, the conversion of grassland to woodland carries potential risks for biodiversity, climate and rural communities. There is therefore a need for careful planning, and a limit to the amount of grazing land which should be afforested.

As explored in Chapter 1.3, there is genuine scope to add to the very large amounts of carbon already stored across the UK's farmed area. For some, however, using this land to graze livestock, even where increases in carbon are being achieved, will almost always come at a major 'opportunity cost' to the climate, because – it is argued – the presence of cattle and sheep prevents the higher levels of carbon storage that woodlands typically provide.[i]

With one of the lowest proportions of forest cover of any country in Europe, there is no denying that the UK needs many more trees.[280] Woodland expansion is essential for improving the nation's biodiversity,[281] and will play an important role in helping the UK reach net zero – partly because of the carbon that trees sequester and partly because timber will be important in replacing emissions-intensive building materials like concrete and steel.[115] However, while achieving these goals will require freeing up some of the UK's grassland (and arable) area for afforestation, planting trees across most of the UK's grazing lands – as has been argued – is both unnecessary and potentially harmful, for several reasons.

First, while there is a legitimate debate to be had about what constitutes an optimal level of tree cover in the UK, **only a proportion of the UK's grassland area 'needs' to be afforested to meet the nation's climate and nature targets.** For instance, the UK Climate Change Committee assumed just under 1 million hectares of grassland conversion to woodland by 2050 in their net zero modelling,[ii] out of a grazed area that totals around 12.4 million hectares.[1] In other words, there is plenty of 'space' for well-managed grasslands in the UK, particularly when all the other aspects of food system sustainability are considered – and this is without much accounting for on-farm sequestration potential, **including through the integration of trees and livestock** which, as seen in Chapter 1.3, is likely to be very significant.

Modelling studies have also shown that meeting these sorts of afforestation targets is entirely compatible with large-scale shifts to agroecological farming systems, in which grazing livestock play a key role. Critically, this would not have to result in any offshoring of food production, providing we shifted to healthier diets, containing fewer calories and smaller amounts of high quality meat and dairy.

RISKS IN CONVERTING GRASSLAND TO WOODLAND

While there are huge social and environmental benefits to be gained from an increase in tree cover, there is a real danger that, without proper planning, converting grasslands to woodland could, in some situations, cause more harm than good, especially where it takes the form of large-scale plantation forestry.[236] Perhaps the biggest area of concern is around impacts on biodiversity, touched on in Chapter 1.4. There are also some social and cultural concerns around large-scale land-use change, as highlighted in Chapter 1.5.

In some instances, the drive to increase woodland cover could even pose risks for the climate. Recent research from Scotland has shown that planting trees on mineral soils with high levels of organic matter (commonly found across the UK's uplands) often results in no net sequestration – and sometimes, net losses – for decades after establishment, thanks to a major loss of soil carbon.[236, 282] This tends not to be a risk on improved pastures, where

i This is when both below and aboveground carbon stocks are taken into account. Woodlands and grasslands often have similar overall SOC stocks, but aboveground stocks are much greater in woodlands, due to the greater amount of biomass in trees compared with grass.

ii It is important to remember that the Climate Change Committee's proposals rest on a range of assumptions around what is practically achievable, and on the level of residual emissions from other parts of the economy. All of these assumptions can be challenged, so its afforestation figures are not a set-in-stone target.

Snowdonia, Wales

lower soil carbon stocks and faster tree growth rates generally result in significant net gains shortly after planting. However, afforestation poses a possible climate threat here too, if the loss of pasture were to lead to an offshoring of food production to parts of the world with more emissions-intensive ruminant farming, or to intensive farming systems that rely on high inputs of feed, fertiliser and fossil fuels. Modelling by the Climate Change Committee has shown that this could happen even alongside reductions in demand for ruminant products – were we to reduce beef consumption by 10% but source more from countries where it is produced at the global average emissions intensity (around twice the average carbon footprint of UK beef), total emissions would still rise by 15%.[115]

So, while there is a clear need to increase the area of woodland in the UK, this should only happen on a portion of our grassland area, and the risks associated with conversion must be managed through careful planning and well-designed policy. Crucially, we also need to remember that there is major potential to grow trees and grazing animals on the same land – the benefits of which for the environment, the farm business and animal welfare are discussed in Chapters 1.3 and 1.4.

2.2 Nitrous oxide: the forgotten greenhouse gas

Summary:

- Intensive agriculture's overwhelming focus on maximising yields requires high nitrogen inputs, particularly from chemical fertilisers, and this leads to large nitrogen losses in the form of nitrous oxide (N_2O) emissions as well as other types of nitrogen pollution.
- Shifting to a biologically based approach to livestock production – where nitrogen inputs, and therefore losses, are lower – could deliver a significant reduction in N_2O emissions.
- Forage legumes have a vital role to play in this – by fixing nitrogen naturally, they enable a major reduction in fertiliser use, and therefore emissions, whilst maintaining high levels of pasture productivity.
- Pasture-based systems typically produce fewer N_2O emissions from manure and slurry than predominantly housed systems. However, further reductions could be achieved through improved storage infrastructure and changes to the timing of spreading manure onto soils.

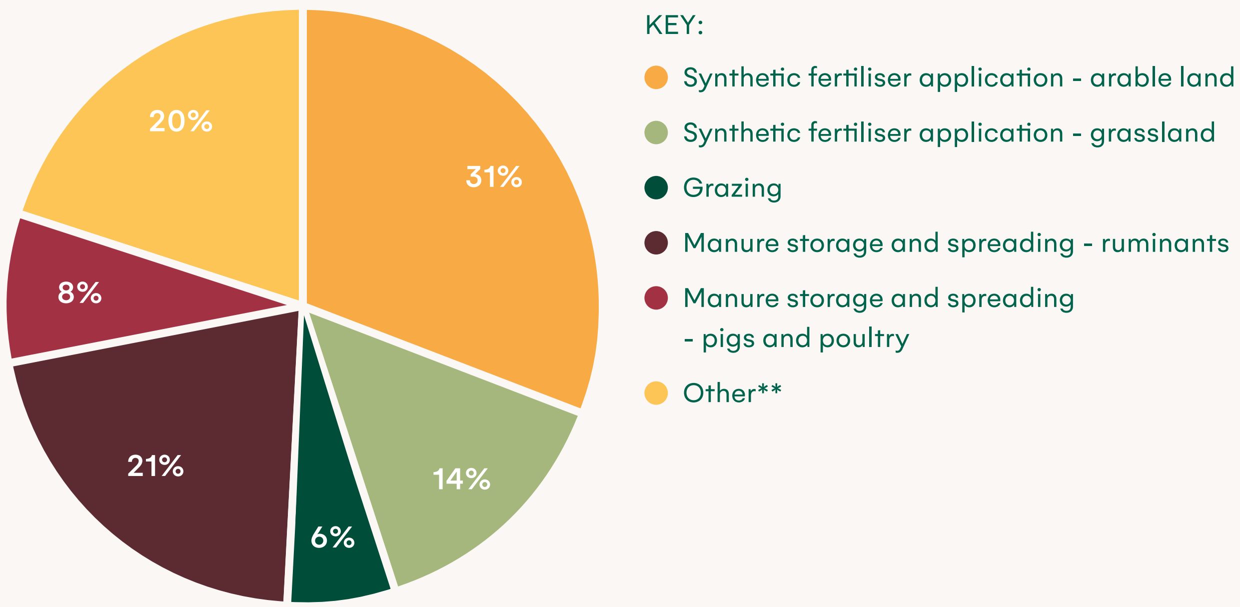
Sometimes termed 'the forgotten greenhouse gas', nitrous oxide (N_2O) is the third most significant climate pollutant after carbon dioxide (CO_2) and methane.[111]

It has a Global Warming Potential over 100 years 273 times that of CO_2, but unlike the similarly powerful but much shorter-lived methane, it stays in the atmosphere for more than a century, meaning the effects of any emissions are both extremely potent and long-lasting.[283] With N_2O also having negative impacts on air quality and the ozone layer, and emissions rising by 30% over the past 40 years (a rate of increase that is exceeding scientists' worst predictions) the need to act is clear.[284]

As the most significant source of N_2O, contributing around 75% and 69% of global and UK emissions respectively, agriculture has a key role to play in meeting this challenge.[284, 285] Most N_2O the emissions come from soils – mainly due to the application of nitrogen fertilisers – but N_2O is also released by livestock directly: through urine and dung deposited on pasture and from the storage and spreading of manure and slurry (Figure 3).

While the UK's agricultural N_2O emissions have fallen by 20% since 1990 (mainly due to a reduction in nitrogen fertiliser use on grasslands, driven primarily by a decline in cattle numbers) they need to fall further.[286] It is difficult to give a precise figure for the reduction needed, not least because any target will hinge upon actions taken in other sectors and on other gases. However, a recent study estimated that a 25% reduction in global N_2O emissions is necessary to stay below the 1.5 °C threshold.[287] The EU's independent scientific advisory panel, meanwhile, has stated that nitrogen fertiliser use needs to fall by 30 to 60% by 2040 to meet climate targets.[288]

FIGURE 3: SOURCES OF N_2O EMISSIONS FROM AGRICULTURE IN THE UK*



* Data from the National GHG Inventory[13]
** Mostly from the management of peatlands used for agriculture

Given that ruminants account, roughly, for nearly 50% of the UK's agricultural N_2O emissions (once the emissions from nitrogen fertiliser used to grow cereal crops for cattle and sheep feed are accounted for),[289] getting rid of ruminants might be viewed as a key means of achieving the necessary reduction in N_2O.

However, as this chapter will outline, **de-intensifying the UK's livestock sector and moving towards pasture-based systems that rely on legumes for their nitrogen supply offers significant mitigation potential,** not just for N_2O emissions but also other forms of nitrogen pollution.

THE PROBLEM WITH EXCESS NITROGEN

N_2O emissions, like other forms of nitrogen pollution (see Box 16), are governed by many factors, but the most important of these is nitrogen loading – the amount of nitrogen applied to a piece of land through fertilisers, animal excreta, manures, biological fixation and/or deposition from the air via precipitation.[290]

Generally speaking, the higher the nitrogen loading, the higher the N_2O emissions, with these tending to increase exponentially as the level of nitrogen input rises.[291] This is a trend that is clearly seen across differing intensities of grassland management.[292] For instance, a comparison of intensively- and less-intensively grazed dairy farms found that the former emitted six times more N_2O per hectare than the latter,[293] while a Welsh study found that N_2O emissions from intensively-managed grasslands were three times higher than pastures with lower stocking rates and no nitrogen fertiliser use.[294]

So, grazing systems with lower nitrogen inputs produce significantly less N_2O, and nitrogen pollutants more generally, than intensive systems. However, minimising nitrogen inputs, and therefore losses, is often overlooked as a mitigation technique since it can result in lower levels of production, as with agroecological practices more generally.

There are two things to say here. The first is to reiterate one of this report's key points, which is that there is a strong case to be made for moving away from very high yielding livestock systems reliant on high levels of inputs, towards those that might be less productive in terms of yield per hectare or animal (when compared with highly intensive systems), but deliver a range of other key benefits, e.g. for biodiversity and animal welfare. This transition would, of course, need to be accompanied by a shift to diets that include smaller amounts of high quality meat and dairy, to avoid an expansion in agricultural land use.[295] It would also require a whole host of changes to agricultural policy and supply chains, to support farmers in making this transition.

While a move to lower input systems can also bring financial benefits for farmers,[3] there are, however, limits to the extent to which livestock output per hectare can be reduced, from the perspectives of farm viability and total food supply. This raises the second point, which is that N_2O emissions from grazing systems can often be cut with no significant impacts on productivity, and many cases an improvement, through the use of forage legumes.

REPLACING SYNTHETIC NITROGEN WITH FORAGE LEGUMES

As noted in Part 1, forage legumes are an essential part of sustainable farming systems. When incorporated into leys and pastures, they help increase resilience to extreme weather, improve forage quality, reduce the need for fertilisers, support biodiversity and sequester carbon, to list just a few key benefits.[207, 296] There are various reasons why forage legumes are so important – their flowers are a valuable feed source for pollinating insects, for example – but the most notable of these by far is their ability to fix nitrogen. This is where rhizobia bacteria form a symbiotic relationship with legumes, converting or 'fixing' inert atmospheric nitrogen into plant-available nitrogen, in the form of ammonia, in exchange for carbon from the plant.

Grasslands containing a healthy proportion of forage legumes therefore rely much less, or not at all, on synthetic nitrogen fertilisers, and this offers major benefits from a climate perspective. This is partly because of **the avoidance of emissions from fertiliser *production*** – an energy- and fossil fuel-intensive process. For every kilogram of nitrogen fertiliser produced, an average of 8.6 kg CO_2e of N_2O and 2.25 kg of CO_2 are released,[207] while globally, the production and transport of nitrogen fertilisers accounts for around 4.4% of all agricultural emissions.[297] Emissions from fertiliser production can also form a significant part of the carbon footprint of conventional ruminant systems – up to 20% for beef, for example.[298]

Reductions in energy use enabled by the avoidance of fertilisers are arguably as important as reductions in emissions. **A comparison of the energy footprints of different dairy systems found that intensive dairies in the Netherlands required 5 MJ of energy to produce 1 kg of milk, whereas grass and clover-based systems in New Zealand that used much less nitrogen fertiliser needed only 1.4 MJ.**[207] With an ever-growing demand for energy, constraints on the amount that can be produced from renewable sources and geopolitical threats to supplies, the ability to fix nitrogen biologically is clearly of huge significance from a strategic and food security perspective.

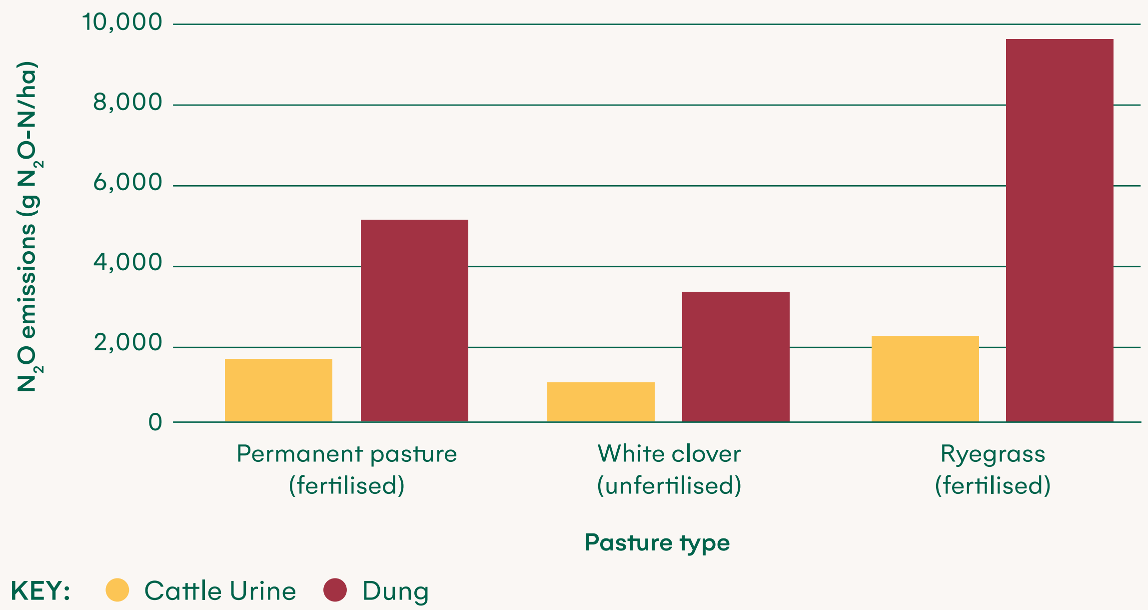
Legumes also reduce the large amounts of N_2O released by the *application* of nitrogen fertilisers.[iii] Grasslands that obtain all or most of their nitrogen from legumes produce significantly fewer soil N_2O emissions than those which rely on nitrogen fertiliser (and/or manure or slurry), an impact that has been observed per unit of forage production, per hectare, and per unit of livestock production.[207, 299-301] Crucially, this reduction often comes with benefits for forage and animal productivity, with various studies showing that swards containing legumes tend to achieve similar, and sometimes even higher, yields at much lower rates of nitrogen application than grass-only pastures.[207]

Two examples of the N_2O reduction potential offered by forage legumes are provided in Figure 4. These findings are from Rothamsted's North Wyke Farm Platform, where emissions per hectare, and beef carbon footprints, were calculated for three types of pasture: an unfertilised grass and white clover pasture, a 'high-sugar' ryegrass sward and permanent pasture given the standard rate of synthetic nitrogen (see Figure 4). As Figure 4 shows, the unfertilised pastures containing white clover produced much less N_2O than the fertilised comparisons, resulting in a 14-21% reduction in beef carbon footprint – results that correspond with findings from Ireland.[25]

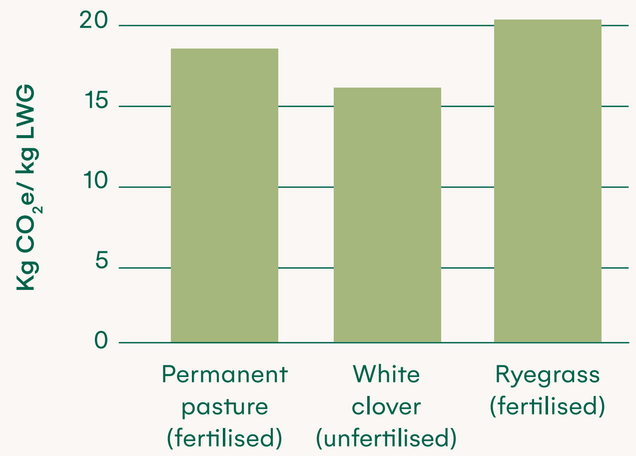
iii One of the reasons for this is that biological nitrogen fixation happens within the root nodules of legumes, meaning the nitrogen is not available to soil microbes in reactive forms, and so is less vulnerable to release as N_2O. Another is that the rate of biological nitrogen fixation is linked to plant demand, and this means that there tends to be less of a risk of soil nitrogen surpluses than when nitrogen fertilisers or manures are applied.

FIGURE 4: REDUCING PASTURE N_2O EMISSIONS THROUGH FORAGE LEGUMES

A: N_2O EMISSIONS PER HECTARE*



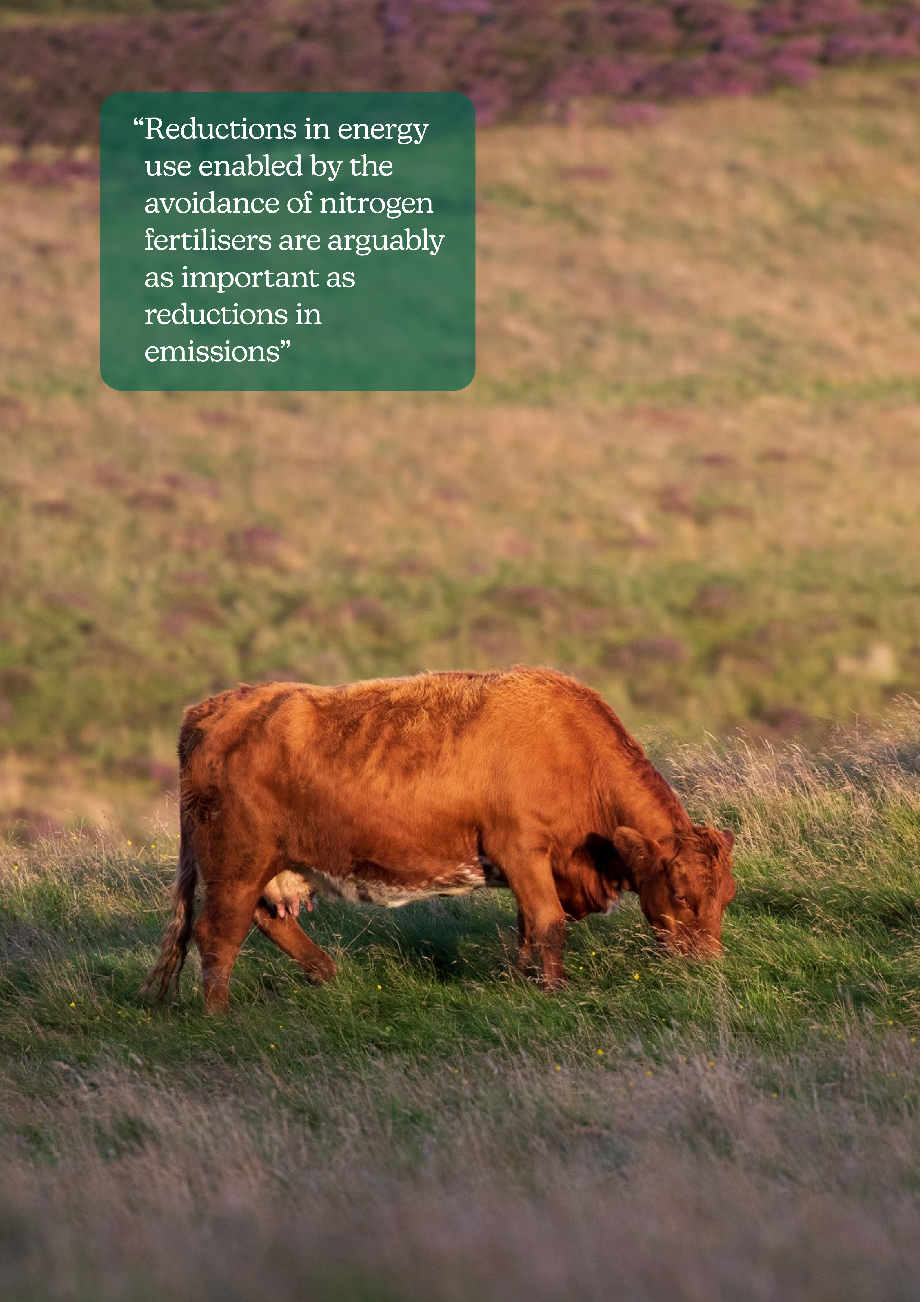
B: BEEF CARBON FOOTPRINT**



Pastures that contain legumes such as white clover, and therefore do not need to be treated with N fertiliser, hold significant emissions reduction potential, as studies from Rothamsted Research have shown. Figure A, for instance, shows that an unfertilised pasture containing white clover produced 34-36% less N_2O per hectare than a N-fertilised permanent pasture, and 52-66% less than a N-fertilised 'high sugar' ryegrass sward.

Figure B, meanwhile, shows what impact this reduction in N_2O emissions has on beef carbon footprint, with animals grown on the unfertilised white clover pasture producing 14-21% fewer greenhouse gas emissions per kg of liveweight gain than those on the N-fertilised swards.

* McAuliffe *et al.* (2020)[14]
** McAuliffe *et al.* (2018)[15]



"Reductions in energy use enabled by the avoidance of nitrogen fertilisers are arguably as important as reductions in emissions"

THE ROLE OF DIVERSE GRASSLANDS

Forage legumes represent one of the most important means of reducing N_2O emissions from ruminant production, but there is also some evidence to suggest that more diverse swards can reduce N_2O emissions, and nitrogen losses more generally, via other mechanisms, too.

For instance, an Irish study looking at grasslands with varying degrees of species diversity found that N_2O emissions per kilogram of dry matter and per kilogram of forage nitrogen were 24% and 41% lower respectively under a six-species mixture of grasses, legumes and herbs, compared with the emissions from a ryegrass monoculture.[302] These results are probably largely explained by improvements in forage yield and nutrient quality (thought to be an outcome of different plants occupying different niches in a complimentary way) and the resulting improvements to livestock productivity. Even relatively simple species mixtures have been found to improve yields – a three-year series of experiments carried out across Europe found that four-species mixtures significantly increased forage productivity, with a significant percentage of this explained by having a combination of slow- and fast-growing plant species.[23]

There is also evidence to suggest that the specific inclusion of plant species, such as plantain and chicory, which contain high levels of chemicals known as 'plant secondary metabolites' (PSMs), might also provide a means of reducing nitrogen losses from grasslands – though how they do this is not entirely clear, with a number of different mechanisms suggested.i[v]

The impact of PSM-rich plants on N_2O emissions requires more research, with the few studies to have looked at this question returning inconsistent results.[27] There is, however, enough evidence to warrant further research into the potential offered by both chicory and plantain. For instance, a New Zealand study found that N_2O emissions from cattle urine patches were almost 75% lower in swards containing plantain, compared with those on conventional ryegrass-dominated swards.[303] This is a result potentially supported by other studies, which have found that nitrogen excretion rates (though not N_2O emissions specifically) are reduced by between 20- 50% in animals that have been grazed on chicory and/or plantain.[304-306]

Chicory could help to reduce nitrogen losses

iv One of these is the higher forage moisture content of both species, which has been shown to increase the number of times per day that grazing animals urinate, which in turn can reduce the nitrogen content of urine. There is also evidence, mostly from New Zealand, to show that chicory and plantain can improve livestock productivity, with potential benefits for the N_2O emissions intensity of meat and milk. However, most of the interest in these species has centred on their high levels of PSMs – compounds, including tannins, produced by plants generally for self-defence. These can inhibit nitrification (one of the two main ways in which N_2O is produced from the soil), and may also limit protein degradation in the rumen, which as outlined earlier may result in improved animal nitrogen use efficiency.[207]

BOX 16

Nitrogen pollution: a broader problem

N_2O emissions are just one part of a much larger nitrogen problem, in which ruminants are both a major cause – and potentially, part of the solution.

Intensive livestock systems produce significant amounts of two other forms of reactive nitrogen – ammonia, an air pollutant, and nitrate, a water pollutant. This is largely due to the often heavy use of fertilisers and protein-rich feeds, and the storage and spreading of large quantities of slurry from housed herds. This tends to result in excessive nitrogen loadings, which then leads to losses to the wider environment – the consequences of which are felt well beyond the farm gate.

The resulting pollution is one of the main drivers of biodiversity loss in the UK. Nitrate runoff is a major cause of eutrophication in freshwater ecosystems – algal blooms resulting from the accumulation of nutrients, which essentially suffocate aquatic life.[307] Atmospheric deposition of ammonia, meanwhile, has caused 95% of England's nitrogen-sensitive habitats to exceed their critical nitrogen thresholds, threatening many species of plants, mosses and lichens.[307, 308]

Nitrogen, and in particular ammonia, pollution also has huge impacts on human health. Studies have indicated that ammonia may influence the early onset of asthma in children living in agricultural areas and cause respiratory illnesses in those who handle livestock.[309] However, the biggest health problem with ammonia by far comes when it reacts with other atmospheric pollutants, forming small particulates that can travel long distances. Agriculture is responsible for 25-38% of urban air pollution harmful to human health,[310] with a recent study estimating that around 48,000 premature deaths a year in the UK are attributable to 'PM2.5', the most dangerous type of particulate formed.[311]

With the livestock sector responsible for around two thirds of the UK's ammonia emissions,[312-314] the need for action is clear. While various measures, including improved manure management have important roles to play, the move towards a food system where livestock are reared in pasture-based systems holds particular emissions reduction potential. This was highlighted by a recent modelling study of a future EU food system (including the UK) which found that a biologically based approach, where intensive livestock systems are phased out and meat consumption is reduced, but where grazing livestock still play a key role, was the only one that reduced nitrogen surpluses – by 85% – relative to the baseline. It also resulted in 57% fewer ammonia emissions, and allowed all other environmental targets relating to fertiliser and pesticide use to be met – something that was not achieved in the sustainable intensification scenario.[295]

REDUCING N_2O EMISSIONS FROM MANURE

Ruminant manure and slurry can be an incredibly valuable source of fertility, including in arable systems (see Chapter 1.1) but it currently also represents a major environmental problem. Twenty one percent of the UK's direct ruminant N_2O emissions, as well as a significant proportion of agricultural ammonia (see Box 16) and at least 15% of methane emissions (see Figure 5) come from slurry and manure.[289] This is mainly due to intensive dairy and beef systems, which produce much more slurry than low input, pastured-based systems. A nationwide transition to a less intensive approach to livestock production, combined with a shift to diets lower in meat and dairy, could, therefore, deliver a significant reduction in slurry emissions – including from the pig and poultry sectors. This would not, though, mean an end to manure and slurry production, as many pasture-based farms, particularly in the dairy sector, require periods of housing, and so efforts to tackle manure and slurry emissions are relevant here too.

One of the ways N_2O emissions can be reduced from manure is by decreasing the protein (and therefore nitrogen) content of feed where intake is high – just one of the potential benefits of moving away from heavily grain-fed production systems (see Chapter 1.2). While more research is required, forage choice may have an impact too – one study, for instance, found that nitrogen losses from slurry were 25% lower where animals had been fed on lucerne rather than ryegrass silage.[315]

Changes to storage and spreading practices also hold the potential for significant emissions reductions. Properly covered manure heaps and slurry tanks tend to produce less N_2O during the storage phase, as well as much less ammonia and methane – though care needs to be taken with how muck is then spread, as greater retention of nitrogen can result in higher field N_2O emissions.[316] This can be mitigated by matching application rates to crop nutrient requirements, and by spreading during the spring and in dry weather; one study, for example, found that doing so reduced direct and indirect N_2O emissions, as a percentage of nitrogen applied, by 54% and 80% respectively.[292] Shallow slurry injection, while less effective as a means of reducing direct N_2O emissions, is also worth highlighting as it tends to significantly reduce ammonia emissions, a major pollutant and an indirect source of N_2O.

> "nitrogen losses from slurry were 25% lower where animals had been fed on lucerne rather than ryegrass silage"

Of course, manure and slurry emissions cannot be looked at in isolation – the whole farm's emissions need to be accounted for. When this is done, grazed systems are sometimes seen to have a higher carbon footprint, per kg of output, than intensive, fully housed systems, due to their higher enteric methane footprint – a finding that is often read as evidence that intensive systems are better for the climate. However, studies have also shown that well-managed, pasture-based farms can produce milk at a similar, or sometimes even lower, emissions intensity than intensive fully housed systems, despite their higher enteric methane output.[317] In fact, in the UK, organic beef, lamb and dairy all have lower carbon footprints than their conventional equivalents, thanks to significantly lower levels of CO_2 (20 to 40% less) and in particular N_2O (16 to 65% less) emissions.[277] It's also vital to note that this approach to assessing climate impact tends to overlook a host of other key considerations – from the emissions and energy used to produce bought-in feed and fertiliser, to the very different atmospheric behaviour of methane, an issue looked at in the next chapter.

BOX 17

The need for better accounting of N_2O emissions

Transitioning to a more sustainable approach to livestock production will require a range of actions, including changes in government support for farmers and shifts in consumer behaviour. But it will also require an accurate understanding of the impacts of different production systems. With this in mind, there is a clear need to better account for the variations in N_2O emissions observed across different grazing systems.

Direct measurement of N_2O emissions is only possible in field experiments, and so to estimate emissions from across the whole sector, representative values for the percentage of N inputs lost as N_2O, known as 'emissions factors' (EFs), are used. Until recently, standard international IPCC EFs (2% for cattle excreta, 1% for sheep excreta) were used to calculate grazing N_2O emissions,[318] but these made some quite basic assumptions. So in 2018 a more accurate, UK-specific excretal EF of 0.44% was developed from a set of field studies, and is now used in the UK's national emissions inventory.[291, 319]

This change in calculation marked a significant improvement, which showed that N_2O emissions from UK agriculture had previously been overestimated by 18%.[291] However, this reduction hasn't yet been factored into the carbon footprint figures commonly given for British beef and lamb – most of which were calculated before the introduction of the new EFs.

There is room for excretal N_2O EFs to be improved further still, especially when it comes to upland and hill grazing livestock, because the new UK-specific excretal EF is based on cattle grazed on lowland mineral soils, a very different scenario to the conditions typically found in the uplands. A recent study carried out in North Wales found that excretal EFs on upland and hill grasslands were 0.11 and 0.08% respectively – substantially lower than the UK figure of 0.44%. The authors also found that if these EFs were applied across the whole of UK's upland area, sheep excretal N_2O emissions in the national inventory would fall by 43%.[320] Given the number of other studies which have found very low excretal EFs in upland grazing livestock systems, there is, therefore, a strong case for the national inventory (as well as upland beef and lamb carbon footprints) to be updated accordingly.[321]

In short, **N_2O emissions from the UK's ruminant sector have until recently been overestimated – and almost certainly continue to be**. With carbon footprints becoming an ever-more important metric, there is a pressing need for current figures to be updated so that they better reflect the current understanding around N_2O emissions from different grazing systems, which in turn will allow for more informed, accurate decisions when it comes to the sustainability of different livestock products.

2.3 The methane debate

Summary:

- While methane emissions from cattle and sheep need to fall, a more holistic – and accurate – assessment of methane shows that pasture-based livestock can play a central role in a climate-friendly food system.
- Because methane is a short-lived gas, an ongoing though reduced level of emissions is compatible with a net-zero future. This is in stark contrast to CO_2, a long-lived gas, the net emissions of which need to be eliminated entirely.
- Debates around ruminant methane need to take a much broader view of the role of cattle and sheep in a sustainable food system. Given the many benefits grazing livestock can provide, there are, therefore, strong arguments against pursuing radical reductions in ruminant numbers as a methane mitigation tactic.
- Still, there is a clear need, and potential, to tackle ruminant methane in a sustainable manner. A growing list of methane reduction strategies are being investigated, and although some of these are highly problematic, many offer real promise for low input, pasture-based systems – now, and in the near future.

All of the benefits provided by grazing livestock ultimately stem from their ability to thrive off forage that humans, and to a large extent pigs and poultry, cannot consume. In doing this, however, they produce methane (CH_4) – perhaps the biggest issue in the debate around grazing livestock.

There are good reasons to be deeply concerned about methane. It is a potent greenhouse gas, the atmospheric concentration of which has more than doubled since pre-industrial times.[322] With levels continuing to rise at an alarming rate, it has become clear that major and immediate cuts in manmade methane emissions will be necessary if we are to have any hope of staying below 1.5°C of warming.[323] In recognition of this problem, various countries, including the UK, have signed up to the 'Global Methane Pledge', which aims to reduce global methane emissions by 30% by 2030 (relative to 2020 levels).[324]

The cause of this surge in atmospheric methane concentrations is not entirely clear. Rising emissions from tropical wetlands, higher than reported fossil fuel emissions, and (possibly) a reduction in the capacity of the atmospheric methane sink, all appear to be contributing factors. There is no doubt, though, that ruminant production is also part of the challenge. Over the past two centuries, a tripling of global ruminant numbers has contributed to roughly 0.2°C of the 1.1°C warming experienced to date, and ruminant livestock are now the second biggest source of methane from human activities after fossil fuels (see Figure 5 overleaf).[325-327]

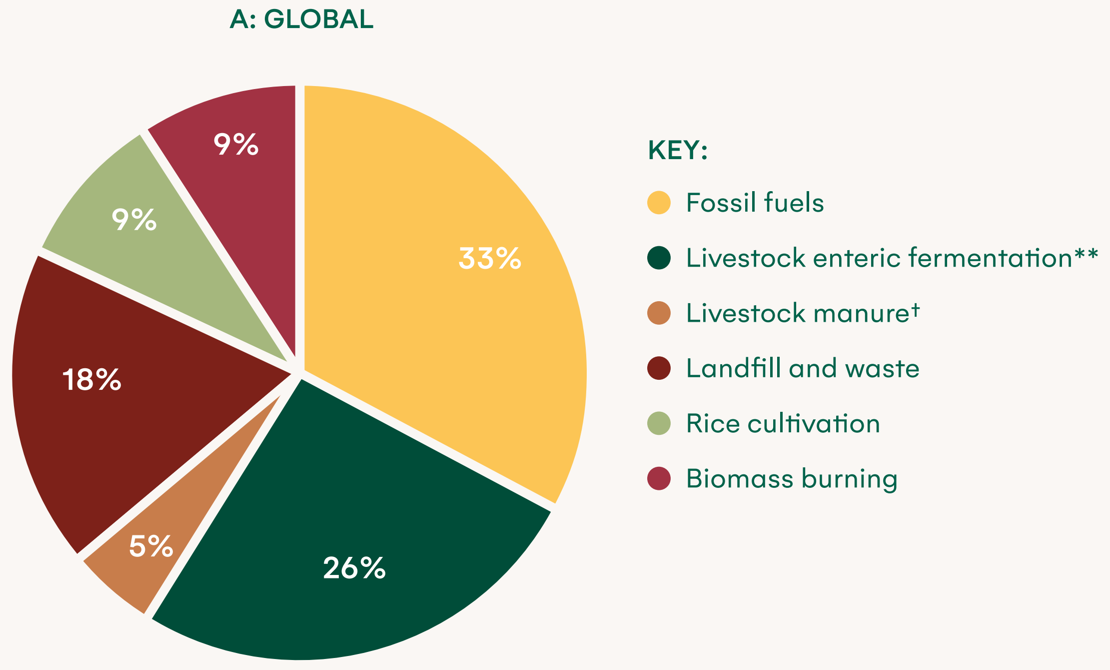
Recently, a debate has erupted around how to deal with ruminant methane, thanks to the development of a new and more accurate way of reporting its powerful but short-lived impact on the climate, termed GWP*.[328, 329] For some, this new metric 'proves' that ruminant methane is not a serious concern, providing its emissions are stable; for others, though, it has only strengthened the case that eliminating ruminant methane emissions represents one of the best means of limiting warming in the near-term.

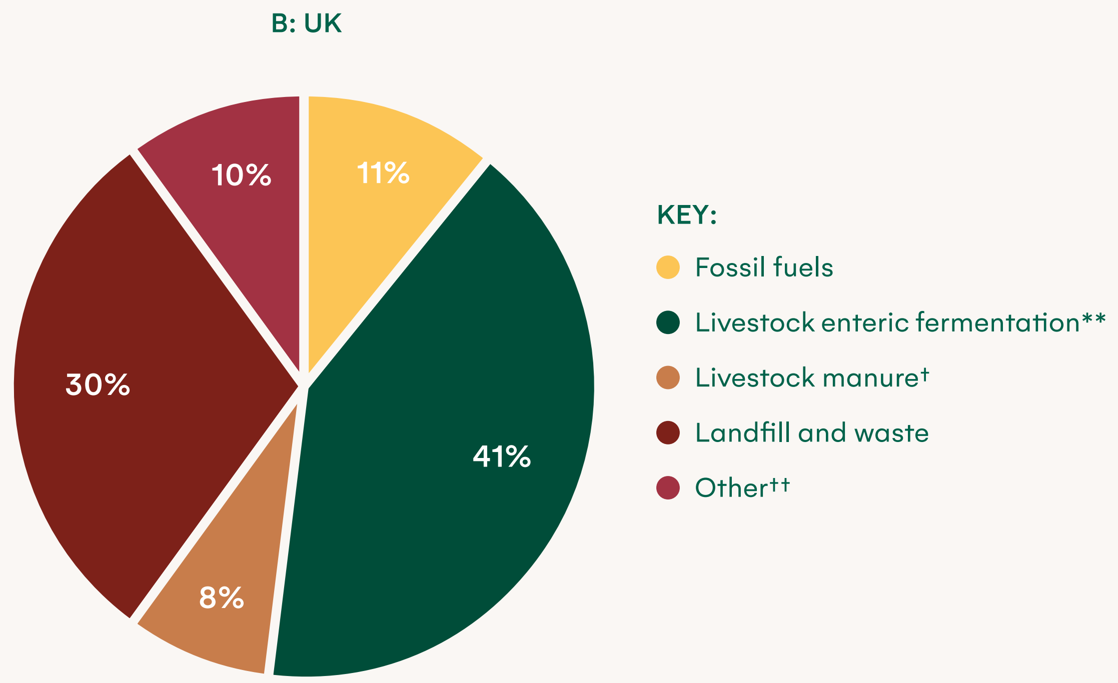
This is a disagreement that, as with the grazing livestock debate more generally, cannot be answered by climate science alone. However, by measuring methane emissions in a more accurate way, and assessing their impact alongside all the other issues relevant to food system sustainability, it is clear that an ongoing – albeit reduced – level of ruminant methane is entirely compatible with a climate-friendly future. This section will outline how and why, and look at how the grazing livestock sector might take action to reduce methane emissions over the coming decade, in ways that bring wider economic and environmental benefits.

HOW METHANE AFFECTS THE CLIMATE

Methane is a hugely powerful greenhouse gas, with a warming impact 80 times greater than that of CO_2 over 20 years.[330] However, the way in which it contributes to warming is fundamentally different to CO_2. When a pulse of methane is emitted, it has a strong initial warming effect before being broken down in the atmosphere after around 10-12 years. In contrast, CO_2 persists almost indefinitely, while N_2O persists for around 120 years, meaning any emission of these gases continues to warm the planet for a much longer period of time than methane.[331]

FIGURE 5: SOURCES OF METHANE FROM HUMAN ACTIVITIES*





* Global data from the IPCC[16] (2021) and the FAO (2022).[17] UK data from the National GHG Inventory[18]

** The process in which methane is produced by microorganisms in the first stomach of ruminants (cattle and sheep) as they help to digest plant matter. The methane is expelled from the animal mainly through belching.

† Methane is emitted from the manure of ruminants (as well as pigs and chickens). The amount produced depends on a number of factors, including whether and how the manure is stored and spread onto soils.

†† Land Use, Land Use Change and Forestry

This fundamental difference in how methane affects the climate is a key issue, but one that is not widely understood outside academic circles. Essentially, if the amount of methane being released into the atmosphere remains stable, it will be broken down at the same rate as it is emitted and no significant increase in warming will occur.[v] If, however, the rate of methane emissions increases (as is currently happening at a global level), the result is a rapid warming effect, due to the increase in atmospheric methane concentrations.

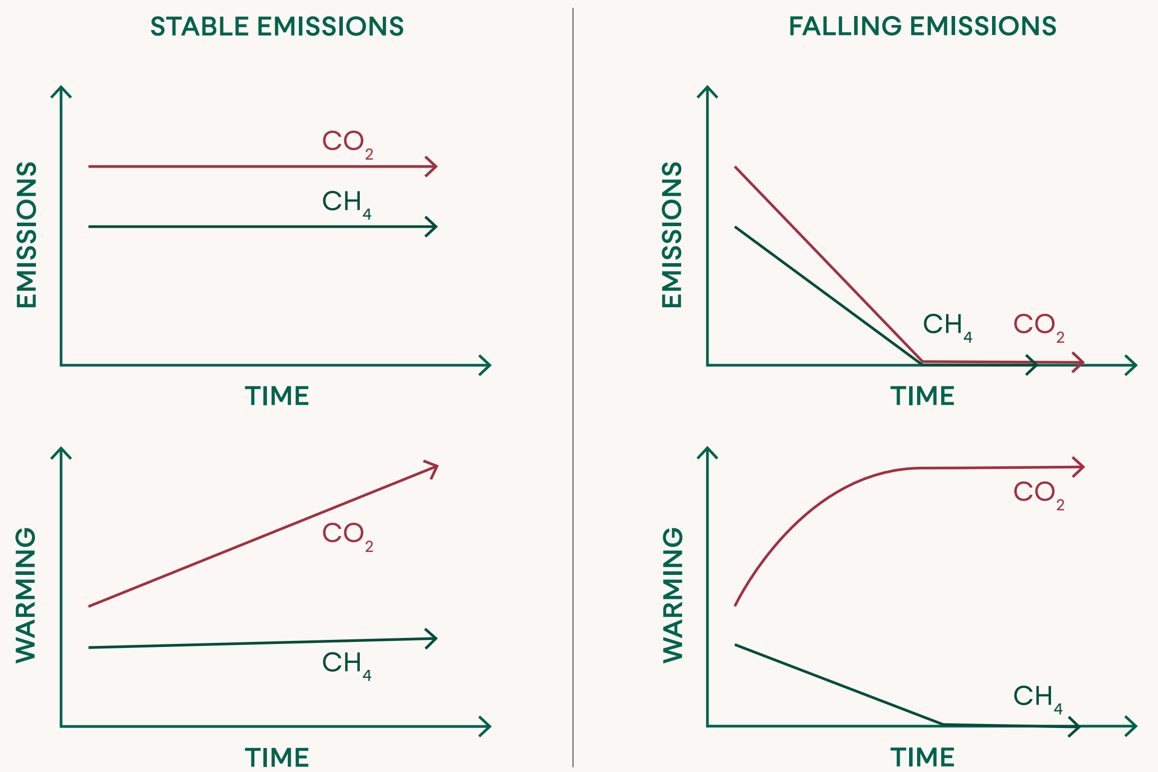
In contrast, any decrease in the rate of methane emissions reverses the warming caused by prior emissions (similar to removing CO_2 from the atmosphere). For CO_2 on the other hand, any ongoing level of emissions leads to a continued increase in warming, and this is why its emissions need to be cut as far and as fast as possible, with any remaining emissions offset through the removal of carbon from the atmosphere. Figure 6 visualises this critical difference in warming impact between methane and CO_2:

v Some warming does occur when emissions are stable due to the slow adjustment of the climate system, but this effect is small and is accounted for under the GWP* metric.

FIGURE 6: COMPARING THE WARMING IMPACT OF CO_2 AND METHANE

Carbon dioxide and methane affect the climate in very different ways - as described in the figures below and in the text above.

While any level of CO_2 emissions will cause significant warming, a stable rate of methane does not.



Reproduced from Allen *et al.* (2017)[19]

BOX 18

Methane, metrics and policy

The very different behaviour of methane to CO_2 is massively relevant to questions around how we best measure and tackle GHG emissions.

The problem with GWP100

Currently, the development and communication of national greenhouse gas reduction targets, as well as the carbon footprints of individual foods, combines the quantity of emissions from different gases into 'CO_2-equivalents' (CO_2e; see Box 14). This is almost always calculated using the GWP100 metric, which weights gases according to their relative warming strength.[111] Aggregating emissions in this way can be useful, especially for systems like agriculture, which produce all three major greenhouse gases. However, GWP100 has always, and especially recently, been criticised because it does not account for the difference between short- and long-lived gases. While this does not mean that GWP100 is necessarily 'wrong', it does mean that it significantly overestimates the warming impact of stable and in particular, declining methane emissions, while significantly underestimating the impact of increasing emissions.[328]

A new metric – GWP*

To address this issue, a new metric has been developed by academics at Oxford University, named GWP*.[328, 329] This metric does account for the lifespan of gases, by considering any changes in the rate of emissions of those which are short-lived, like methane, rather than just the level of emissions. In other words, GWP* can be used to more accurately reflect the impact of current or predicted emissions trajectories on global temperature over time, by measuring emissions in terms of 'CO_2-*warming* equivalent' rather than the somewhat more arbitrary 'CO_2-equivalents'.[333]

No perfect metric

GWP*, like any metric, is imperfect. For example, arable farmers introducing livestock as part of a mixed farming system could be penalised for increasing methane emissions when GWP* is used, even if their system as a whole is more sustainable and resilient, and overall UK ruminant methane emissions are falling in line with national reduction targets.[333] There are other potential equity-related issues with GWP*, discussed on page 110.[334, 335] But the continued use of GWP100 also risks unfairness, as it will always penalise grazing livestock for releasing methane, even if significant reductions in emissions, compatible with national or sectoral methane targets, are being made. Continuing to use GWP100 also risks putting the most pressure on methane emitters to undo all of their historic warming whilst CO_2 emitters need only reach net-zero to prevent further warming.[334]

Moving forwards

For these reasons, there is general agreement that we need to use a range of equivalence metrics (e.g. GWP100 and GWP*) to enable a better understanding of climate impact. The most critical action, however, is to set individual targets for different gases, reflecting the differing levels of action that are needed for CO_2 (net zero emissions) and methane (a reduction, but not an elimination).[336]

New Zealand has already adopted this approach: in its climate plan, all CO_2 and fossil methane emissions are to be reduced to net-zero by 2050, whilst biogenic methane (agriculture and waste) is to be reduced by 24-47% (a set of figures produced by IPCC modelling of pathways that could limit warming to 1.5°C). Methane mitigation targets will, of course, depend on a country's specific circumstances – some examples of which are discussed later in the chapter. The general principle, however, is a key one: **having a reduction target (instead of a net-zero target) for methane would help enable more effective climate policy, and embed within wider thinking the critical point, that an ongoing – albeit reduced – level of methane emissions is entirely compatible with a stable climate.**

Now, as already mentioned, the differences in atmospheric behaviour between methane and CO_2, and the use of the GWP* metric, have been interpreted in very different ways. Some have argued that the limited amount of warming caused by a stable rate of methane emissions means that only very minor reductions in methane are required; others, however, argue that GWP* further emphasises the need for immediate reductions in methane as a means of limiting warming in the near-term.[332, 337] This disagreement cannot be settled by climate science alone – broader concerns around equity, food system sustainability and feasibility are all critically important issues in the debate around what we do about methane. Nevertheless, the climate science literature does make some things clear.

First, meeting the world's climate targets will not require an elimination of methane – unlike CO_2, which absolutely does need to be eliminated (with any remaining emissions offset by carbon sequestration). As a recent review into ruminant methane emissions noted: **"While the need to reduce the dominant, long-lived greenhouse gas CO_2 to zero is unambiguous, the same does not apply to methane, owing to the different lifetimes of these gases and temperature response to their emissions"**.[338] This is a critically important point, that needs to be properly understood by policymakers, as well as the general public (see Box 18).

That said, given the amount of warming that has already occurred, there is no credible way the world can limit temperature rise to 1.5°C, or perhaps even 2°C, without reductions in global agricultural methane emissions. In other words, capping agricultural methane emissions at current levels is almost certainly incompatible with achieving the world's climate targets.

There is also, however, a real risk that focussing too heavily on methane could distract from the necessary actions on CO_2. Scientists have pointed out that **while rapidly reducing methane emissions would help us to stay below 1.5°C of warming by 2050, in the longer term reducing CO_2 emissions is far more important for meeting the target of no more than 2°C of warming by 2100.**[339] It is worth noting here that, unlike for methane under the Global Methane Pledge, there is no specific global strategy for tackling CO_2, even though 2023 saw the largest annual increase in CO_2 emissions experienced to date.

WIDER SOCIAL AND ENVIRONMENTAL CONSIDERATIONS

So, ruminant methane emissions need to be reduced, though not eliminated, if we are to meet our climate targets. As already mentioned, though, the debate around ruminant methane encompasses a much broader range of issues. One of the most important of these is equity. While GWP* is more accurate from a scientific perspective, some have raised concerns that its use might entrench global inequalities.[335] This is because it could be interpreted in a way that favours developed countries or large meat and dairy companies whose methane emissions are stable, or who are more easily able to reduce them through existing technologies. These countries and companies would then be able to claim a negative or neutral warming impact, despite having contributed significantly to historic warming when establishing their large herds in the first place.[335, 337] Conversely, countries whose ruminant numbers are increasing from a lower base, and who in many cases would benefit nutritionally from an increase in meat and dairy consumption, could be penalised because of the strong warming impact of their rising emissions.

It is important to reiterate that GWP* does not inherently lead to unfair outcomes. Nevertheless, each country's climate (and methane-specific) targets must reflect their individual responsibility and capacity to reduce emissions, as the Paris Agreement states.[340] For this reason, even though the UK's stable rate of methane emissions is not causing considerable 'additional' warming, our status as a developed, high GHG-emitting country means we arguably have an obligation to go further and reverse some of the warming previously caused.

> "The climate science makes it clear that an ongoing, albeit reduced, rate of methane emissions is compatible with achieving our climate targets"

The Paris Agreement also, however, notes the importance of accounting for local circumstances.[340] The fact that the majority of the UK's agricultural area is unsuitable for crop production, meaning that grazing livestock represent the only form of farming possible across many areas, is obviously relevant from this perspective. Allied to this is the fact that the UK is particularly well suited to pasture-based ruminant production and, as already discussed, produces some of the lowest carbon footprint ruminant products in the world.[278] Clearly, then, there are very strong social and economic arguments for avoiding drastic cuts to ruminant production in the UK. It also needs remembering that other sectors of the economy hold methane reduction potential too – as Box 20 outlines, cost-effective action on landfill and energy emissions could go a long way towards achieving our near-term methane reduction targets.

A 'natural baseline'?

Arguments around ruminant methane also need to account for the many key benefits that well-managed grasslands and grazing livestock offer in the UK – including for biodiversity. This brings up an interesting argument around the extent to which methane emissions from ruminant livestock have, in effect, replaced those produced by wild ruminants, and are therefore part of a 'natural baseline'. Wild ruminants once produced large amounts of methane – one study, for instance, estimates that global ruminant methane emissions in the Late Pleistocene, prior to the mass extinction of megaherbivores, were perhaps only 15% lower than today (though there is considerable uncertainty around these figures).[325]

Of course, many cattle and sheep, including in the UK, are currently managed in ways that deliver no real benefits for biodiversity – in fact, quite the opposite – so treating the emissions from these ruminants as in any way 'natural' is difficult to justify. And while there are no estimates for what the 'natural' ruminant methane baseline might have been in the UK before humans arrived, ruminant livestock numbers today are perhaps 10 times greater than wild ruminant numbers were 7000 years ago, prior to the arrival of agriculture (though again, there is a huge amount of uncertainty around these estimates).[341]

Still, for those grazing systems that do at least partly replicate the ecological role of wild herbivores, there is a strong argument to be made that some of the methane they produce could be considered part of a natural baseline – especially in the many instances where pure rewilding is not possible or desirable. How exactly this might be accounted for is a difficult question to answer, though one interesting approach to factoring biodiversity into carbon footprint analyses is touched on later on page 122.

BOX 19

Tackling methane emissions from other sectors

Ruminants are far from the only source of methane in the UK, and reductions in other sectors could go a long way towards meeting the UK's commitment under the Global Methane Pledge.

Fossil fuels

Fossil fuel extraction and use accounts for 35% of methane emissions from human activity globally (see Figure 5), a large proportion of which are 'easily' avoidable. The International Energy Agency has estimated that around 70% of methane emissions from the fossil fuel sector could be mitigated simply by detecting and fixing leaky infrastructure, capturing gas from abandoned extraction sites and introducing a ban on routine flaring.[342] The amount of methane lost to the atmosphere in this way is also thought to be significantly underestimated in many countries' national inventories, meaning mitigation could go even further in tackling global warming than previously believed.

While these 'fugitive' emissions make up a smaller proportion of the UK's national inventory (around 11%) than elsewhere, action in this area could still reduce national methane emissions by 9% by 2030, according to the Green Alliance.[343, 344] We already possess the means of achieving these reductions, and doing so would be cost-effective for fossil fuel companies, though policy and regulation to hold them to account is lacking.

Landfill

The UK has significantly reduced emissions from landfill in recent decades. However, progress has stalled, and the waste sector still represents around a third of the UK's total methane emissions (Figure 5).[343] If the UK were to ban landfilling of organic waste by 2025, alongside greater incentives to capture more gas from landfill, it could enable a reduction in national methane emissions of around 19%. by 2030.[344]

Effective methane mitigation in the landfill and waste sectors could reduce the UK's methane emissions by 28% by 2030, almost enough to reach our commitment under the Global Methane Pledge.[344] Both approaches are associated with minimal trade-offs, and are highly cost-effective and technically feasible in the short-term – providing the Government acts now.

ACTING ON RUMINANT METHANE

Of course, just because the UK can almost meet its 2030 methane reduction targets by acting on energy and landfill emissions alone, does not mean that ruminant methane can be ignored. While there are many arguments against slashing UK ruminant numbers in the pursuit of drastic cuts to methane, it is also clear that reductions in ruminant methane emissions will be required over the next few decades – not just because this will be necessary for meeting our climate targets, but also for reasons of equity.

Critically, these reductions must be made as part of a broader transition to a biologically based food system, where the production and consumption of animal sourced foods becomes more aligned with what we can sustainably produce. As discussed in Chapter 1.2, in the UK this will likely entail a major decline in pork and poultry consumption, but a more moderate reduction in the amount of dairy and beef consumed – a reflection of the central role ruminants, and the much more limited role monogastrics, would have to play in an agroecological food system. Still, while the picture will vary from region to region, there's little doubt that globally, we will need to see a reversal of the ongoing increase in meat and dairy production and consumption.

Cutting cattle and sheep numbers is not, though, the only way in which methane emissions can be reduced. An ever-growing list of methane reduction strategies for livestock are being investigated and many offer real promise. **It is imperative, however, that these measures do not compromise the overall sustainability of ruminant production systems, animal welfare or human health. This means ensuring that mitigation strategies are targeted at, or at least applicable to, pasture-based, agroecological systems, and do not risk entrenching, or even supporting, the expansion of intensive housed systems.**

This is a concern that applies to some of the strategies currently in development, including a number of feed supplements mentioned below. It also applies to some existing methane mitigation strategies, such as the increased use of feed concentrates to reduce finishing times in beef systems, and the use of maize to improve milk yields in the dairy sector. Both of these measures tend to reduce enteric methane emissions per kilogram of output, but a greater reliance on arable feed, animal welfare impacts and, particularly in the case of maize, increased soil erosion, are all associated issues of serious concern.

Actions available now

There are a number of methane reduction strategies that are compatible with pasture-based systems, including those which can be implemented now (Table 4 overleaf).

Many of these involve improving the efficiency of production. For instance, taking measures to improve animal health by tackling common diseases such as Bovine Viral Diarrhoea, Johne's disease and mastitis, could reduce total GHG emissions from the national herd/flock by around 10%.[345] Reducing calving intervals, meanwhile, could deliver a 7.5% reduction in emissions from the Scottish beef herd (Table 4).[346] Both of these changes would likely bring benefits for profitability and productivity.

Another practice available now, though with much less certain mitigation potential, is the move to more diverse pastures, especially those rich in herbs and forage legumes like sainfoin and bird's-foot trefoil. These plants contain high concentrations of tannins, which are thought to have a methane-reducing effect when consumed by animals.[347] Some studies have observed a significant impact - one study from New Zealand,[348] for instance, saw a 32%

reduction in methane per kilogram of milk solids in cows grazed on bird's-foot trefoil compared with cows grazed on ryegrass. Others, however, have not,[27] and more research is therefore needed. This includes into practical challenges around the use of high-tannin species, to ensure they can be grown and consumed in high enough quantities without compromising productivity.[207]

Willow, which is also high in tannins, represents another possibility. Introducing small willow trees as part of silvopastoral systems has been found to reduce methane emissions in some circumstances by around 20%. Again, though, more research is required, to confirm whether reliable reductions in methane emissions might prove yet another benefit provided by the integration of trees and livestock – a practice explored further in Chapters 1.3 and 1.4.[349, 250]

TABLE 4: POTENTIAL WAYS TO REDUCE METHANE EMISSIONS FROM GRAZING LIVESTOCK

Strategy	Mitigation potential**
Actions available now:	
– Improved herd and flock health	– 10% reduction in UK ruminant emissions
– Reduced calving interval	– 7.5% reduction in Scottish beef emissions
– Smaller cow size	– 5% reduction in suckler beef herd emissions
– Improved slurry/manure management	– Variable
– Diverse pastures and willow*	– Variable
Possible future actions :	
– Selective breeding for low methane	– Could reduce methane by 20-60% in the beef herd after a decade of breeding
– Natural feed additives (e.g. Asparagopsis)	– 20-98% depending on dosage and overall diet composition

While achieving a transition to a climate-friendly food system will not require the 'zeroing out' of ruminant methane emissions, these do still need to be reduced, including in the UK. Some mitigation strategies come with potentially major problems from a wider sustainability perspective, and so real care needs to be taken in how any reductions are pursued. However, there are ways in which methane emissions from pasture-based systems might be sustainably tackled, now and in the future. The table above highlights a selection of these.

* While some promising results have been observed, more research is needed to be able to estimate mitigation potential

** Based on a range of sources.[20]

BOX 20

Reducing methane from slurry and manure

At present, around 15% of the UK's agricultural methane emissions are estimated to come from manure and slurry, and 83% of this is produced by slurry, and 83% of this is produced by ruminant livestock, particularly dairy cows.[351] However, the true figure may be much higher – in recent years, research has increasingly found that the emissions factors used to calculate methane emissions from slurry may be massively underestimating the amount produced in reality.[352] European slurry emissions, for example, may be twice as high as current emissions factors would suggest.[353]

What this might mean for the carbon footprint of dairy and beef produced from intensive, fully housed systems (which produce much more slurry than pasture-based systems) is not clear, but it does raise serious questions about the supposed climate benefits of rearing animals intensively.

This does not mean, of course, that it is wrong to ever keep cattle indoors – particularly during the wetter winter months when keeping livestock off the land can help protect soil health, for example. While some producers have successfully been able to adopt systems that involve no housing, for many this will be a struggle, and so taking steps to reduce manure and slurry emissions represents an important action for low-input, pasture-based systems, too.

Methane emissions from slurry stores can be almost entirely eliminated, by properly sealing and then capturing any gas produced.[354] This biogas can then be used on-farm or fed into the grid, thereby producing a 'double' climate win by also replacing the need for fossil fuels. While anaerobic storage of slurry can also reduce N_2O emissions (see Chapter 2.2), care needs to be taken in how any slurry or digestate is then spread onto fields, to avoid any unintended 'pollution swapping'. Smaller farms in particular face challenges around covering their slurry pits, though new technologies are being developed to tackle this.

"biogas can then be used on-farm or fed into the grid, thereby producing a 'double' climate win"

For solid manure, composting tends to reduce methane emissions (by up to 70%), and also helps to retain nutrients which can improve soil health and reduce the need for synthetic fertiliser.[355] The Japanese fermentation technique known as Bokashi may also hold promise – something that a three-year Innovative Farmers trial is currently investigating.[356]

Possible future actions

Moving forwards, a number of new strategies with greater emissions reduction potential are being developed – though again, caution is needed for the reasons outlined on page 113.

Selective breeding

Selective breeding of animals that naturally produce lower levels of methane is, from a pasture-based perspective, perhaps the most promising potential strategy. Numerous projects are underway in various countries, including at Scotland's Rural College (SRUC), where recent research has found that strongly selecting for low methane production can permanently and cumulatively reduce emissions by 17% of the mean per generation – a level of reduction that appears to be possible across a range of breeds and production systems.[357] If scaled up, this could provide a 20-60% overall reduction in methane emissions from the cattle herd after a decade of breeding, depending on the intensity of selection. For context, this is a level of reduction broadly similar to the 24-47% reduction target by 2050 set by the New Zealand Government.[358]

There are, of course, other traits which need to be considered in breeding plans, although breeding for low-methane has not yet been associated with negative trade-offs.[354] In fact, low-methane animals often tend to show improved feed conversion efficiency, health, meat yield and even nutritional value.[357] While the figures above are only potential mitigation values, the SRUC are currently working with others to move this work forward as part of a four-year project.[359] If this approach to breeding does prove possible, it could become a relatively straightforward, low-cost option for farmers from the next decade onwards, including for those using native breeds.

A methane-reducing vaccine?

Scientists are also working to develop a vaccine that could inhibit the activity of methane-producing microorganisms in the rumen. Early studies have found this to be effective in a laboratory setting, but the same effect has yet to be seen in live animals.[360] More research is needed, but if it were to prove viable, and providing there are no negative side effects for animal or human health, then it could hold promise for pasture-based systems.

Methane-suppressing feed supplements

The strategy that has received the most public focus to date, is the use of methane suppressing feed supplements. In essence, these are substances which, when mixed with feed, can reduce the amount of enteric methane produced. A large number of products have been investigated with varying levels of success, but the three which have received the most attention are a chemical additive known as 3-NOP and sold as Bovaer® (which is already approved for use in the UK and EU), a type of red seaweed called Asparagopsis, and chemical nitrates.[361]

Studies have shown that all of these supplements can be effective at reducing methane emissions in the ruminant systems they have been tested in: nitrates have been found to reduce methane emissions by around 10%,[362] 3-NOP by approximately 20-40%,[363] and Asparagopsis by 20-98%,[354] with most of the variation due to dosage, overall diet composition and type of ruminant. Given their efficacy, feed additives have been recommended as a key means of achieving methane reductions in the UK, including by the Climate Change Committee.[364]

There are, however, some major challenges and concerns with this approach. Perhaps the biggest is that methane suppressing supplements are currently only suitable for systems that involve housing, as they need to be fed at least once daily as part of a mixed ration. If care is not taken, efforts to incentivise the use of feed additives could, therefore, favour intensive and fully-housed systems, potentially at the expense of pasture-based systems. One possible solution is to develop slow-release boluses or mineral licks which could deliver the supplements to grazing animals – an approach that holds real promise, though it is too early to say whether these could reach the same level of efficacy and consistency.

It is also unclear how effective supplements might be in the longer term, with some research suggesting that 3-NOP, for instance, may become less effective over time, at least in high-forage diets.[365] Some supplements, meanwhile, may pose a risk to animal health: nitrate, for instance, can cause severe illness or even death in cattle when administered incorrectly.[354]

While questions over the health impacts of supplements derived from natural ingredients, like seaweeds, have also been raised, these may be more readily accepted by organic farmers and the public. Many coastal communities have fed seaweed to their livestock for centuries,[366] and the diet of North Ronaldsay sheep in Orkney consists of more than 90% seaweed.[367] However, while scaling up seaweed production could deliver social, economic and environmental benefits, there are also challenges, especially since Asparagopsis species are not native to the UK.[366]

Some brown seaweeds, which are native to UK waters, are also being investigated, along with a range of other natural plant-based additives like essential oils. So far, none of these seem to be anywhere near as effective as Asparagopsis, and many can only be incorporated into the diet in small amounts for health and palatability reasons.[368, 369] While it might be possible to combine multiple compounds to achieve a greater overall effect, there is currently very little published research on this.[354]

There are, then, various concerns around some of the proposed means of tackling ruminant methane – risks which are more likely to materialise if too much focus is placed on reducing the methane intensity of ruminant products. However, some of these practices could still make an important contribution to methane mitigation in a biologically based systems over the medium term.

Selective breeding has potential to reduce methane emissions

2.4 Measuring climate impact

Summary:

- We need to adopt a more holistic approach to assessing the sustainability of food and farming systems, including when it comes to the measurement and communication of climate impacts.
- At present, climate impact is largely measured using a narrow set of emissions and land use intensity metrics (e.g. CO_2-equivalent per kg of product), which often overlook the provision of key outputs (e.g. on-farm biodiversity and micronutrients). When studies have accounted for these, the carbon footprints of pasture-based livestock products are often significantly improved when compared with industrial livestock equivalents.
- While improving the way individual product footprints are calculated is important, we also need to look at the carbon footprint of the whole food system. From this perspective, grazing livestock can be seen to have a central role in a climate-friendly future.

We know that well-managed grasslands and grazing livestock can deliver a whole host of benefits to society. We also know that there should be significant scope to reduce GHG emissions, and store more carbon, by moving towards a lower input, more pasture-based approach to ruminant production, as part of a wider food system transformation that includes a shift to healthier, more sustainable diets.

However, to realise these benefits, we need to understand, measure and communicate the sustainability of different foods and production systems in a more holistic manner.

LIFE CYCLE ASSESSMENT

The main way sustainability is assessed today is through attributional life-cycle assessments, or ALCAs for short. These measure the inputs, outputs and impacts associated with producing a particular food, the results of which are generally expressed as product-specific footprints or 'foodprints' – CO_2-equivalent emissions per kilogram of product being the most widely-known example. ALCAs are an important tool in efforts to improve the sustainability of the food system, not least because they have helped increase public awareness around the environmental impacts of farming. There are, however, various issues with ALCAs and how the product-specific footprints they generate are currently calculated and used.

One of these is the risk of **unrepresentative or inaccurate data being extrapolated**. For example, we know that N_2O emissions from livestock grazing on upland and hill farms are currently overestimated in inventories and carbon footprints (see Box 17), while methane emissions produced from slurry may be understimated (Box 20).

There are also a range of key outputs and impacts which are extremely difficult or even impossible to measure on a per kilogram basis – farm resilience and human and animal welfare being just two examples.

Then there is the issue that **some of the most commonly used metrics do not always provide an accurate approximation of environmental impact.** As discussed in the previous section, the standard (GWP100) equivalence metric does a poor job of conveying the actual climate impact of methane – something that GWP* addresses to an extent (see Box 21 overleaf). There are similar issues when it comes to the use of land use footprints as a measure of biodiversity impact. This is an important metric, but one that does not necessarily tell us how harmful (or indeed, beneficial) the use of the land is for nature. For instance, it typically takes more land in total to produce a kilogram of extensively reared beef than it does to produce a kilogram of intensively reared beef. However, well-managed grazing is hugely important for a wide range of habitats and species, whilst land used to grow the ryegrass silage and cereals typically consumed in intensive beef systems generally has very little biodiversity value. This is a major and obviously relevant difference that total land use footprint, as a metric, does not capture.

BOX 21

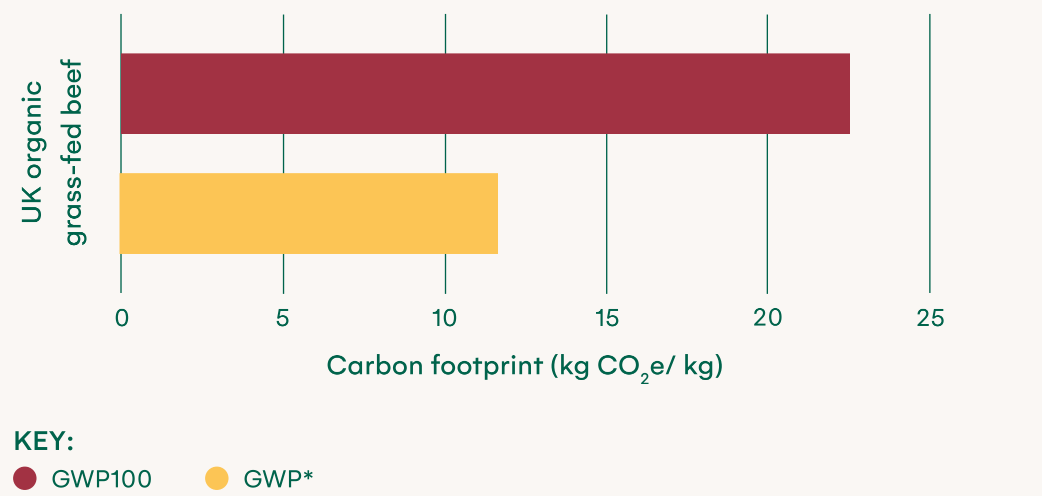
Methane measurement in carbon footprints

As explained in Chapter 2.3, the standard GHG equivalence metric, GWP100, does a poor job at conveying the actual warming impact of methane emissions over time - an issue that a new metric, GWP*, was developed to address.

The choice of which metric is used can therefore make a major difference to our understanding of climate impact - as illustrated in the figure below. In this scenario, where methane emissions are assumed to be stable, the use of GWP* instead of GWP100 almost halves the carbon footprint of 1kg of UK organic beef.*

GWP*, like any metric, is an imperfect tool. However, it can help provide a more informed understanding of the climate impact of methane and, more broadly, ruminant livestock: one that recognises that an ongoing, though reduced, level of ruminant methane emissions is entirely compatible with a climate-friendly food system.

FIGURE 7: CARBON FOOTPRINT OF BEEF – GWP100 AND GWP*†



* "Data from Smith et al. (2019)[21] Includes N_2O, CO_2 and CH_4 emissions.

† If methane emissions were instead assumed to be rising, the GWP* value would be higher than given here; if they were falling, the GWP* value would be lower.

Accounting for nutrition in carbon footprints

The conclusions drawn from life-cycle assessments also depend on what is being measured. At present, almost all footprints use units of measurement based on mass (e.g. GHG emissions per kilogram of product), or on the mass of a single macronutrient (e.g. GHG emissions per 100 g of protein). However, 100 g of beef is nutritionally very different to, say, 100 g of beans (see Chapter 1.2). This means that the current way we measure carbon footprints partly overlooks the basic function of food: nutrition.

The potentially perverse consequences of this are illustrated by a study that compared the GHG footprints of meat, milk and dairy products, frozen and processed fruit and vegetables, and grains.[370] Using the mass-based approach, meat products performed the worst by a wide margin. However, this was reversed using an energy-based (i.e. calorie) functional unit, which resulted in fruit and vegetables having the highest footprints because of their very low energy densities. At the same time, 'unhealthy' foods like sweets and biscuits had the smallest environmental impact using an energy-based unit of measurement.

No-one would suggest, of course, that a diet high in sweets and biscuits and low in fruit and vegetables, is nutritionally sufficient – quite the opposite. Using grams of protein, or indeed any single nutrient, as the functional unit of measurement risks generating similarly odd conclusions.

In recognition of this, academics have started exploring how the overall nutritional value of different foods can be better incorporated into life-cycle assessments. This is mainly being done using nutrient density scores (NDS), which are calculated by combining the content of a range of essential nutrients within a food, relative to dietary requirements, into one score. There are several indexes, each incorporating a slightly different assortment of essential or 'qualifying' nutrients, with some also incorporating 'disqualifying' nutrients, applying a 'penalty' to nutrients that should be discouraged in the diet, such as sodium and (short chain) saturated fats.

> "the current way we measure carbon footprints partly overlooks the basic function of food: nutrition."

While the exact results vary depending on the index used, multiple studies have demonstrated that incorporating nutrient density in life-cycle assessments substantially reduces the gap between plant and animal products when it comes to their carbon footprints, and largely eliminates the difference between monogastric and ruminant meat. This is due to the typically greater nutrient density of ruminant meat compared with both monogastric meat and plants (see Chapter 1.2).

For instance, a UK study found that when the carbon footprints of different meats were measured using a nutrient index, beef had a similar climate impact to both chicken and pork (see Figure 8).[298] Another paper found that the arable land-use footprint of beef was similar to that of chicken and pork when measured per 100 g of meat, but was around one third the size of chicken's and half the size of pork's when measured using a nutrient score.[371]

These results show that a fuller accounting of nutritional value can dramatically change the comparative climate impacts of different foods. However, even accounting for nutrient density in this way is, arguably, inadequate. The relevance of a food's nutritional density will at least partly depend on the wider dietary context, and so taking this into account provides a much better basis for assessing the relevance of its nutritional value for carbon footprint analyses.

Take beef as an example. It provides a range of key micronutrients, but in a diet where consumption of animal-sourced foods and the nutrients they deliver is surplus to dietary requirements (as is the case for many, though not all people in some high-income countries today), its nutrient density becomes less relevant to the assessment of product-specific carbon footprints. However, in a diet where animal-sourced food consumption is lower, and the supply of nutrients they provide is, therefore, more limited, the nutrient density of beef becomes much more relevant.

A Swedish study demonstrated the importance of this dietary context, by comparing the carbon footprints of different foods based on their essential amino acid contents across a range of different diets.[372] In the context of the average Swedish diet, minced beef had the highest carbon footprint of the foods studied. However, when placed in the context of a hypothetical lower-meat diet, the relative impact of minced beef was massively reduced, to the extent that it actually performed better than chicken and minced pork (see Figure 8). In short, then, while the high nutrient density of, say, a steak may be relatively unimportant in diets where animal-sourced foods are over-consumed, it is much more important in healthier diets lower in meat and dairy.

Accounting for ecosystem services in carbon footprints

Focusing solely on a farming system's edible products, such as meat and milk, when calculating environmental footprints can also be reductive. On an intensive beef farm, for instance, this is arguably fair, given that the overwhelming focus is on meat production. Other farming systems, however, are more multi-functional, producing food, fibre and, in the case of well-managed grazing systems, many ecosystem services, such as biodiversity and soil health benefits. In recognition of this, researchers have been developing new ways of accounting for these other 'outputs' in life-cycle assessments.

For instance, a recent study attempted to allocate the carbon footprints of different Swedish beef and dairy systems not just to meat and milk, but also to the provision of ecosystem services, in recognition of the fact that each system 'produced' differing levels of public goods.[373] This was done by economic allocation – i.e. emissions were attributed to the different outputs based on how much these were 'worth', with the value of ecosystem services in this instance measured using agri-environment payment rates. For the most extensive beef system (the one providing the most ecosystem services) 48% of the total carbon footprint was allocated to the delivery of ecosystem services, resulting in a reduction in the carbon footprint of the beef produced by almost half, from around 34 kg CO_2e per kilogram of carcase weight, to around 18 kg (see Figure 8).

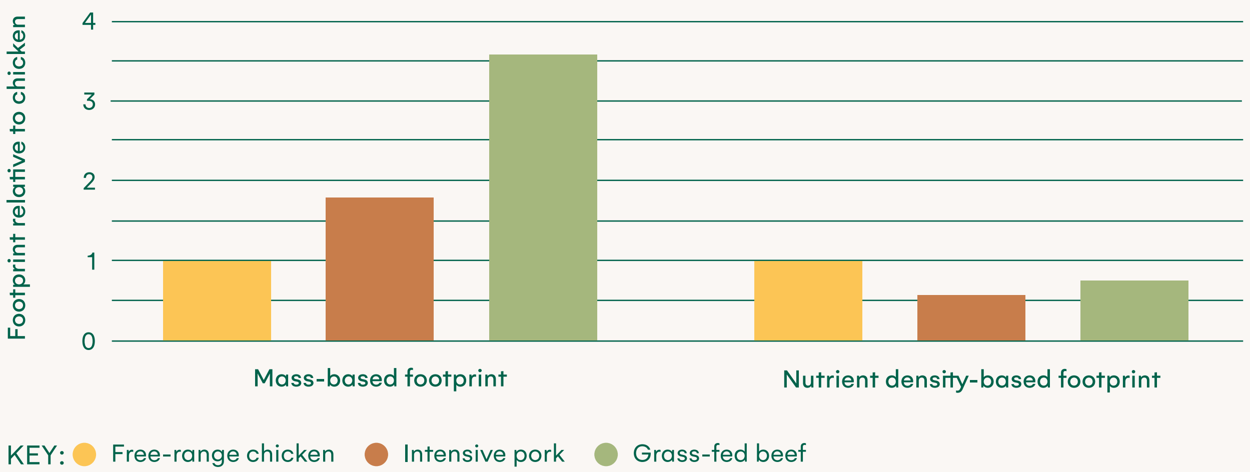
Other studies have attempted to account for the social and cultural goods that livestock systems can provide. One interesting example comes from a Kenyan study which compared the carbon footprints of smallholder dairies with intensive ones.[374] When emissions were only allocated to milk production, conventional, intensive dairying had the smallest footprint. But when factors like manure and the importance of cattle for farmers' finances and livelihoods were treated as 'outputs' to which emissions could be allocated, the difference in carbon footprint between the two systems vanished.

FIGURE 8: TAKING A MORE NUANCED APPROACH WHEN MEASURING CARBON FOOTPRINTS

At present, the carbon footprint of food is generally expressed as emissions per kg of product (e.g. CO_2e/kg of beef), or per kg of protein (e.g. CO_2e/kg of beef protein). This approach, however, overlooks various key considerations – including the provision of other farm 'outputs', like micronutrients and biodiversity.

The three figures below illustrate how accounting for these two outputs can dramatically alter our understanding of climate impact, with ruminant products from multifunctional, nature-friendly farming systems performing much more favourably than when a standard approach to measuring carbon footprints is used.

A: CARBON FOOTPRINT OF MEAT, BASED ON MASS AND NUTRIENT DENSITY

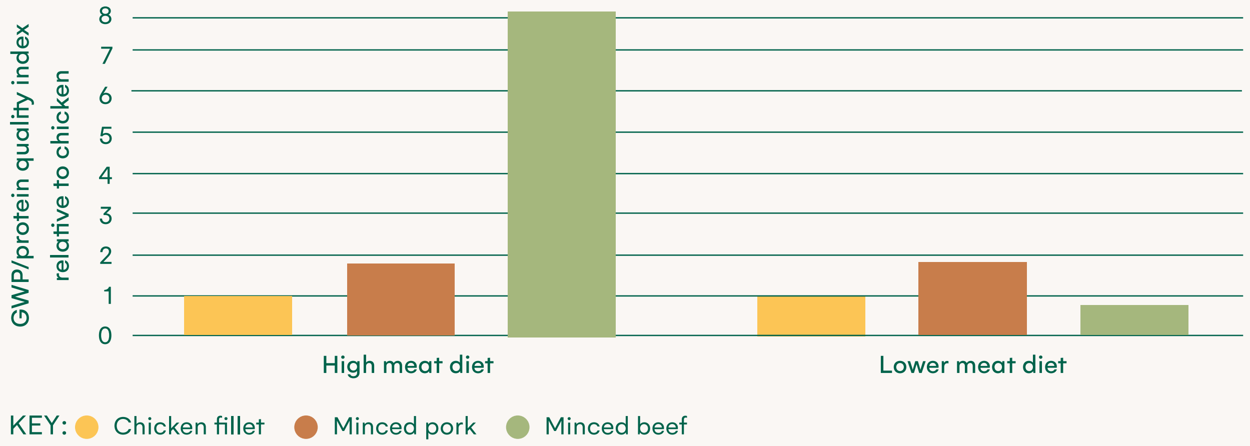


A: Nutrient density

The figure above is adapted from a case study which illustrated how nutrient density could be accounted for when calculating the carbon footprints of different meats.* When footprints were measured in the standard way, as emissions per kg of product (the left-hand panel) grass-fed beef was found to have a footprint almost 4 times greater than free-range chicken, and nearly 2.5 times greater than pork. However, when footprints were calculated in a way that accounted for nutrient density (the right-hand panel) the differences between beef, pork and chicken were massively reduced, with beef even having a slightly lower footprint than free-range chicken. This is because beef is particularly nutrient-dense.

* Carbon footprints of different meats are expressed relative to the footprint of chicken. See McAuliffe et al (2018) for original data.[22]

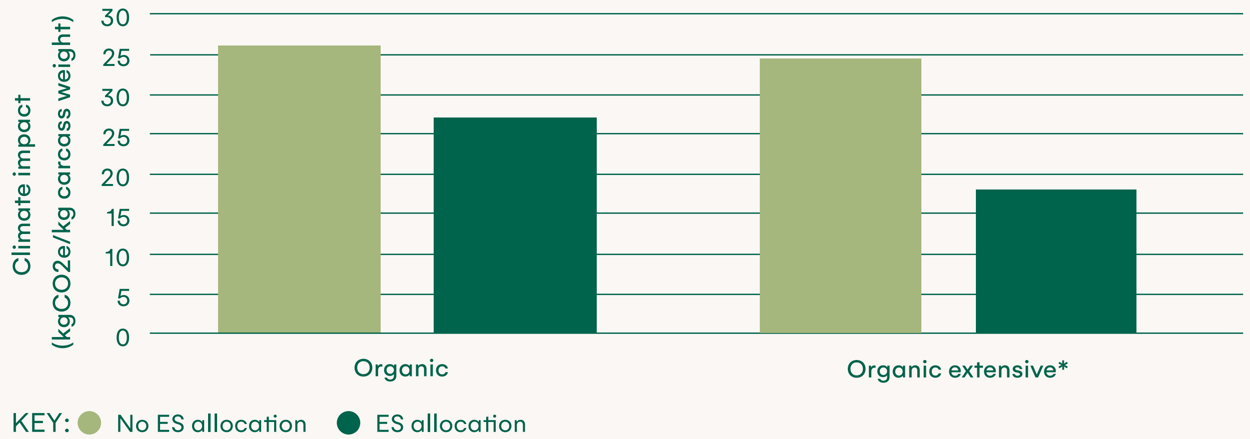
B: CARBON FOOTPRINT OF MEAT IN DIFFERENT DIETARY CONTEXTS



B: Dietary context

Wider dietary context has a major bearing on the relative importance of an individual food's nutritional profile – as illustrated by a Swedish study,[23] shown in Figure 8B. The left-hand panel shows a high meat diet, where there is an oversupply of nutrients provided by meat. Because the high nutrient density of beef is considered relatively unimportant in this scenario, beef was found to have a carbon footprint 8 times greater than chicken. However, in a low meat diet, the nutrient density of beef becomes highly relevant, resulting in beef having a footprint 20% lower than chicken.

C: CARBON FOOTPRINT OF BEEF WHEN ACCOUNTING FOR ECOSYSTEM SERVICES



C: Accounting for other ecosystem services

Some studies have attempted to incorporate non-food outputs, like biodiversity, into carbon footprints. For instance, Figure 8C shows results from a study that allocated emissions from different beef systems not just to meat and milk, but also to ecosystem services (ES) produced.[24] Both of the systems shown produce important ES, as shown by the significant drops in their carbon footprints when ES were accounted for (the dark green bars). However, the 'organic extensive' system saw an even greater fall in footprint because it had greater biodiversity and used an endangered native livestock breed.

TAKING A WHOLE SYSTEM PERSPECTIVE

In short, accounting for a broader range of variables in ALCA can provide a more informed understanding of the sustainability of different livestock systems. Doing so also tends to show multi-functional grazing systems in a much more favourable light than is usually the case at present. However, a few points need remembering here. For a start, ruminant foods still tend to have higher individual footprints than plant foods when nutritional value, for example, is accounted for – though liver, with its extremely dense nutrient profile, is a notable exception.[375]
It is also important to recognise that another novel LCA approach – the inclusion of 'carbon opportunity costs' in carbon footprint calculations – tends to generate even larger footprints for pasture-based ruminant products than in conventional analyses. A carbon opportunity cost is effectively the amount of potential natural vegetation regrowth and, therefore, carbon sequestration that a food's production is seen to prevent. Because beef and lamb tend to require more land than other foods, they are seen to prevent a greater amount of sequestration – and, hence, have a greater carbon opportunity cost.[376]

Now, there are various questions around the inclusion of carbon opportunity costs in footprint calculations: how can we be sure that any potential sequestration will actually be realised, and is this even desirable from a wider sustainability perspective? The second question, in particular, touches on a broader point, which is that **product-specific footprints, even when calculated in a more holistic way, will always have their limits.** As one paper concluded, "Unless we appreciate that ALCAs can only take us so far, we risk making decisions based on incomplete information, which may ultimately fail to provide the predicted benefits, or even result in unanticipated negative consequences."[377]

There are various reasons for this, some of which are highlighted earlier in the chapter. But one of the main ones is that assessing sustainability solely on the basis of product-specific footprints risks missing the bigger picture. Take, for example, the intensification of livestock production. This tends to reduce emissions intensity per kilogram of product – and so, it is often argued, is beneficial for the climate. However, if these improvements are outstripped by increases in production and consumption, the net effect, across the whole system, will be a harmful one. Termed Jevon's Paradox, this phenomenon is a very real risk.[279] In Sweden, for example, the emissions intensity of chicken production fell by a fifth between 1990 and 2005, but because consumption almost doubled, total emissions – which is ultimately the measure that really matters – increased by 150%.[378]

The Netherlands also provide a cautionary tale, for related reasons. Here, decades of intensification have reduced emissions intensity, leading to claims that the Dutch agricultural sector is one of the world's most sustainable. However, as production has increased, local pollution issues have worsened dramatically, to the extent that the government is now having to consider drastic measures, including major cuts to livestock numbers. The issue is that, ultimately, there are absolute environmental limits which we need to stay within, a fact that risks being ignored if we continue to focus largely on how efficiently we can produce a kilogram of food.

It is, therefore, fundamentally important that we take a whole system, UK-wide view of the impacts of food production and consumption, to ensure that we actually achieve our targets for climate, the environment and public health. From this perspective, it becomes much clearer that farming systems that deliver a range of public goods, but which will often be lower-yielding and, therefore, more land and emissions intensive per kg of product, can still play a central role in a food system that achieves the necessary reductions in emissions and land use – providing, of course, levels of production and consumption are aligned accordingly.

For instance, modelling from Wageningen University has found that a European food system containing some livestock would actually produce fewer greenhouse gas emissions and use less land overall than a completely plant-based scenario – despite plant foods tending to have the lowest individual carbon footprints.[31, 45] This is because in diets with less than 18 g of animal protein per person per day, a greater risk of nutrient deficiencies was found to occur, and addressing this shortfall required more consumption of plant foods – and, therefore, more land for (and emissions from) crop production. The same research also found that if animal protein consumption was reduced in Europe, ruminants would become the most important livestock species, due to the high nutritional value of their meat and milk and their ability to upcycle forage.[45]

The value of taking a whole system view is also illustrated by modelling carried out for the Food Farming and Countryside Commission. This found that a nationwide transition to agroecology, with grazing livestock playing a key role, could lead to a 55-70% fall in the UK's agricultural emissions whilst freeing more land for woodland creation – providing we simultaneously transitioned to more sustainable diets, key to which is a reduction in the amount of animal-sourced food we consume.[33]

It is important to remember that, as with all models, these studies represent just two possible visions of a future food system, and can be challenged in lots of ways. Still, what they both show clearly is that taking a whole system perspective often provides a quite different understanding of the climate 'friendliness' of different foods and farming systems to when emissions intensity metrics alone are used. It is for this reason that researchers have called for climate impact to be looked at from a much broader range of perspectives.

By doing so, we can gain a more accurate and nuanced understanding of what role a food might play in a climate-friendly future. Crucially, though, this broader assessment of climate impact needs to be part of a genuinely holistic consideration of all aspects of sustainability – one that avoids carbon tunnel vision, and instead accounts for a range of key issues, from climate resilience and adaptation, to animal welfare and the needs of rural communities.

CASE STUDY

Edinglassie

Malcolm Hay

The name Edinglassie is derived from the Gaelic “Eudan-glasaich” meaning “steep grazing”. It is an upland estate with 120 native breed suckler cows, including 20 pedigree beef shorthorns, 400 Lleyn X ewes and 350 pure Blackface ewes.

25 years ago, Malcolm’s farm system was heavily reliant on artificial fertiliser, producing large amounts of silage to see their heavy continental-breed cattle through the winter. These practices, along with a succession of wet winters, resulted in highly damaged, poached fields, which sparked their conversion to organic and the use of native breeds better suited to the steep, wet ground.

Edinglassie is a good example of a Highland estate where grazing by sheep and cattle plays a crucial role in helping to maintain habitats, including grasslands and wetlands of high biodiversity value. By maintaining an open sward, well-managed grazing has enabled a wide variety of small plant species, many of conservation interest, to thrive, without being outcompeted by more dominant, common species. At the same time, grazing pressure is low enough to support healthy populations of taller and more palatable species, like ragged robin and juniper. This means Edinglassie has a very rich and structurally diverse flora. The quality and diversity of habitats on the estate, which also include native woodland, heath and bog, support many other endangered species, including black grouse, snipe and curlew.

Crucially, the transition to organic has also brought financial savings through the elimination of expensive inputs and breeding their own replacement stock, along with the premium received for organic beef and lamb.

FARM TYPE

Organic upland beef and sheep

LOCATION

Upper Banffshire, Northeast Scotland

SIZE

4,600 acres

- 400 acres ploughable
- 600 acres of permanent pasture
- 3,600 acres of heather hill

“The organic system has, for me, provided an invaluable template for farming in an environmentally sensitive manner while still retaining an economically viable and productive agricultural business.”
Malcolm Hay

Conclusions

This report supports a major proposition: that it will be difficult, if not impossible, to transition to biologically based farming systems that address climate change, restore nature and improve public health, without the integration of grazing livestock.

This conclusion stands in opposition to much of the current thinking around the role of livestock in our food system, which either casts all forms of livestock farming as inherently unsustainable, or views more intensive livestock production, particularly of pigs and poultry, as a 'better' option than grazing systems.

These characterisations have come about for various reasons. There are, of course, very real issues surrounding the way many ruminants are reared today, which urgently need tackling. Another reason, however, concerns the way sustainability is commonly assessed. To date, this has often been done through a narrow focus on carbon and land use footprints, expressed per kg of product – a perspective which almost always shows grazing livestock in a 'bad' light, but which also tends to overlook a host of key considerations (for instance, animal welfare, feed-food competition and on-farm biodiversity) that well-managed grazing systems tend to score well on. At the same time, the potential offered by lower input, biologically based farming systems, of which grazing livestock are often a key component, has been massively under-explored.

To overcome these deficiencies, we need to assess sustainability in a more holistic way, and gather much better baseline data on the impacts of different farming systems. For this to happen, though, there will need to be a more fundamental shift in thinking around what we expect from our farmed land – away from an overwhelming focus on yield, towards a broader emphasis on producing nutritious food alongside a wide range of ecosystem services.

Our ability to move towards a sustainable food system where grazing livestock play a positive role will depend largely on the decisions of those who shape the way we farm and eat. However, every section of society will need to work together to meet this challenge. New regulatory frameworks and financial incentives which prevent further degradation and shift the balance of advantage towards truly regenerative systems will need to be prioritised. And action must also be taken to ensure that everyone has access to nutritious and sustainable food, not just those on higher incomes.

Ultimately, our key ask is for all actors to differentiate between the farmed animals which are part of the problem, and those that can play a central role in tackling the climate, nature and public health crises.

Our most important priorities for action are outlined below.

RECOMMENDATIONS

1. Policymakers

Develop and deliver against a holistic and integrated food and farming strategy that identifies clear social, environmental, public health and food security objectives. Joined-up thinking across government departments will be necessary to ensure that different policies work together to support the necessary transition in land use, farming practice and diets.

Provide adequate financial incentives to enable farmers to transition to biologically based farming practices that deliver multiple ecosystem services, including the provision of high-quality nutrition. This should be based around an ambitious, whole farm package of government support that also includes more targeted actions (e.g. grants to encourage the re-integration of livestock into arable rotations, as well as hedgerow and agroforestry creation). The creation of a strategic plan for grasslands, similar to those that already exist for peatlands and woodlands, could aid in this (as Plantlife and others have called for). To enable this transition at scale, government must also invest in the necessary supporting infrastructure, including small abattoirs, to facilitate a functional supply chain.

Strengthen the application of the 'polluter pays principle' to ensure financial accountability for the negative impacts that farming practices may have on the environment and human health. This would help encourage a reduction in the use of agrochemicals and intensive livestock management practices.

Mandate the use of a common framework of metrics for measuring whole farm sustainability as part of future farm support schemes, recording the climate, nature and social outcomes of farming practices. Frameworks, including the Global Farm Metric, are already being adopted and have major potential to empower farmers' decision-making.

Level the playing field for farmers by ensuring that import standards for animal products reflect equivalency with UK legislation, to mitigate against the unintended consequences of importing 'cheap' poor quality meat and dairy.

Work with the supply chain to ensure that shifts in farming practice and diets are equitable and part of a just transition, with no-one left behind. For farmers, policies which deliver fair prices will be key to this, as will those which better support tenant farmers. The government must also act to ensure that every citizen, regardless of financial position, has access to healthy and sustainable food. More ambitious procurement will have a key role to play here, as will an expansion of existing support schemes for those on low incomes.

2. The scientific community

Prioritise research into the climate, nature and social impacts of a large-scale transition to biologically based farming practices. Since 2010, less than 1% of UK agricultural research funding has gone towards studies investigating agroecological farming, massively hindering development in the sector and leaving major evidence gaps (e.g. around the impacts of more diverse pastures on emissions, productivity and soil carbon, including at depth). Research is, therefore, urgently needed into the 'multifunctional' potential of regenerative grazing practices, including into the development of more holistic methods of assessment.

3. Farmers

Showcase examples of best practice and facilitate farmer-led knowledge exchange to demonstrate the potential offered by pasture-based systems. There are many examples of farmers who are already delivering on climate, nature and health, such as those included within the Sustainable Food Trust's Beacon Farms Network. These farms can offer a platform for sharing skills and knowledge around biologically based farming practices, such as the integration of trees, rotational grazing, and the re-integration of livestock into arable systems. Agricultural advisory services could play a key role in facilitating this, but these too need support from government.

4. Farm auditors and certifiers

Play a central role in measuring the impacts of different farming systems against agreed government priorities, not just on carbon, but also on wider environmental and social outcomes. Frameworks such as the Global Farm Metric and farm measurement tools such as Soil Association Exchange are already being developed to provide certifiers with the means to measure and collect data on the impacts of various farming systems using a harmonised audit. The common use of such holistic measurement systems would not only relieve farmers of the overwhelming financial burden of multiple audits but also provide key evidence of supply chain and product sustainability.

5. Food companies and retailers

Develop incentives or mechanisms that accelerate and de-risk the transition to regenerative practices for farmers. This must include paying farmers a fair price for their products but could also include product premiums, price guarantees and long-term contracts.

Ensure that consumers are given full transparency on where and how the food they purchase has been produced. Clear labelling based on harmonised sustainability data, which provides accurate information about the impacts of different foods on climate, nature and health, will be key to this.

6. Funders

Help 'prime the pump' for the agricultural transition by supporting early-stage ideas and collaborations. This should include: the development of common measurement systems; financing skills development and public education on farms; investing in local food and capital infrastructure; and rewarding farmers who participate in trials. For instance, if a food business wants to part-fund the production and procurement of a regenerative food product, this could be matched with philanthropic donations.

7. The general public

For those who are able, source food from truly sustainable and regenerative systems. The need for an informed body of public opinion about the story behind our food has never been greater but enabling this will require action at multiple levels. For instance, government must take seriously the need for food and farming education in schools and on farms, and retailers must provide clearer information around the climate, nature and health impacts of different livestock products. More fundamentally, we need to ensure that every person has access to, and a meaningful say in, the supply of good food – something that is far from a reality at present, but which many citizens want, as the Food Farming and Countryside Commission's Food Conversations work has shown.

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