UK SHEEP FARMING AND THE SUSTAINABILITY AGENDA

A FULLY REFERENCED RESEARCH REVIEW OF THE EVIDENCE AND WAYS TO DELIVER MORE

HEALTH • ENVIRONMENT • PEOPLE • ECONOMICS

In association with

School of Sustainable Food and Farming

National Sheep Association
is an organisation that represents the views and interests of sheep producers throughout the UK. It is funded by its membership of sheep farmers and its activities involve it in every aspect of the sheep industry.

This is an NSA publication in partnership with the School of Sustainable Food & Farming at Harper Adams University. It is the full research review, which is summarised in a shorter report of the same title. Find the shorter repot at www.nationalsheep.org.uk/our-work/policy.

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REPORT AIMS

- Emphasise the global sustainability challenges faced by society.
- Investigate UK sheep farming and assess its sustainability across a wide range of metrics and global needs.
- Explore the trade-offs when trying to meet sustainability goals.
- Explore the positive and negative outcomes of global trade sustainability within the sheep sector.
- Identify what more could be done by sheep farmers to improve sustainability, and the mechanisms needed to make this happen.
- Showcase positive sustainability on UK sheep farms via case studies.

NSA intends for this report to inform and influence what happens both now and in the future in areas of policy support, market development and practical applications at farm level.

CHAPTER 1

What is sustainability? Why is it more than just carbon?

Sustainability is not just a buzz word but an imperative and National Sheep Association (NSA), as a charitable company working in the long-term interests of its members, feels a responsibility to contribute to the quest for greater planetary sustainability in its widest sense.

Many associations are making sustainability claims, without the truth to support them. NSA sees the need to accurately assess the current environmental, social and economic sustainability of sheep farming while also considering what changes the sector will need to adopt to further improve. This report provides answers and direction, but also raises important questions and identifies the areas where further work needs to be done.

The natural landscape of Northern Europe, including the British Isles, is grasslands dominated by grazing ruminants. Sheep have been in the UK since the Neolithic settlers landed on our shores around 3,000-5,000BC. Established over thousands of years, sheep farming in the UK has influenced upland and lowland landscapes, the countryside and communities across the breadth of our nations. It has shaped farmland ecology and had a significant role in culture and heritage.

Sheep farming has also carved out a position of being traditional, good for animal welfare, providing conditions that allow for natural behavioural characteristics to be displayed, and still provides an achievable first step for new entrants on the farming business ladder. But the world has changed considerably, with the pace of change increasing over the last century.

NSA views sustainability in the widest sense including animal welfare, natural resources, landscape management, provision for nature, healthy communities and localised and circular economies, the impact on the wider environment well beyond the farm boundary, and of course the viability and longevity of sheep farming businesses.

Sheep farming pre-dates climate change challenges and would be expected to rank highly on the general sustainability scale through its close connection with the land and nature. But that doesn't mean we can't do more, not just to reduce our carbon footprint, but to be recognised as one of the solutions to the challenges faced by future generations.

Seeking sustainability in its widest sense is a luxury, an indication of plenty. When a society has all its basic needs of food, water, shelter and wellbeing met, it's almost inevitable it will examine wider values and considerations, recognising the trade-offs that can happen between societal needs, ethics and values. Yet sustainability is ultimately driven by need – for example, human survival will be uncertain if we don't have clean air and water, a secure supply of food, and farmers will not be in a position to consider wider environmental and animal welfare values if their businesses are not profitable.

Multi-functionality and holistic thinking are essential factors behind true sustainability, but these are concepts that many people find difficult to understand, preferring to consider their area of interest (for example carbon footprints, animal welfare, food security, rural society or biodiversity) in isolation from wider factors. Unintended wider consequences from actions expected to be good for a singular outcome are often not adequately explored. Chasing productivity alone neglects the potential for environmental gain delivered by farming and, likewise, focusing on the environment may negate farm viability and food security. Therefore when assessing farm sustainability, environmental, economic and social/cultural aspects all come into play and must be considered in concert.

WHAT IS SUSTAINABILITY?

NSA considers sustainability to be defined as a balance between four pillars[3].

1. Environmental responsibility.
2. Economic viability.
3. Health of people, animals and ecosystems.
4. Social acceptability.

CHAPTER 2

The rationale for holistic sustainability assessments and the risks of focusing on single metrics

Balanced livestock farming lives hand-in-hand with the environment, supporting a circular bioeconomy. The primary aim of sheep faming is to produce food and fibre, yet it is essentially a form of land multi-functionality where the aims of food production and environmental outcomes are equally important.

True sustainability means a holistic view must be taken or we risk looking at elements in silos with unexpected and potentially undesirable consequences. All farming systems and management practices influence the environment, whether positive or negative. This includes impact on the landscape appearance; air, water and soil quality; and biodiversity and habitat provision. But we also know many plant, insect, bird and mammal species are dependent on grazing animals and their effect on vegetation.

Sheep farming has created and maintained some of the most-loved landscapes we see and enjoy today. It is no accident most of UK national parks are in areas predominated for generations by grassland and sheep. Analysis of great landscape paintings depicts, more often than not, a river cutting through a grassland valley supporting grazing ruminants, evoking feelings of natural beauty, safety and home.

Not surprisingly this unique environment, working for most times in harmony with sheep farming, is highly valuable in relation to water management and quality, carbon sequestration and nature, but also provides people with social and health benefits, such as open space for exercise tackling obesity and space for mental wellbeing. Public Health England recognise the importance national parks bring in improving human health.

CASE STUDY: **William Egerton**

Sheep and beef enterprise on a 200-acre family farm in the lowlands of County Fermanagh

Through whole-farm soil sampling, William has been able to correct pH, potassium and phosphorous, reduce fertiliser use and improve overall soil health.

"So far I have been able to graze the same amount of livestock on the same area of land with 50% less artificial fertiliser," says William, adding that fewer applications has also saved on diesel and reduced soil compaction caused by tractor tyres on fields.

"This has had a positive effect on the financial sustainability of the farm and reduced the carbon footprint. Multi-species swards are also helping reduce anthelmintic usage on farm and are having a positive effect on daily liveweight gains."

Having struggled with excessive rain and weeds when encouraging clover and establishing multi-species swards, Williams says: "I think more trials and experiments on how to grow clover and multi-species swards in wet, challenging conditions, and also showcasing the benefits they can have on anyone's farm would encourage other farmers to take this practice on."

Therefore, it's essential these environments are maintained not only as honey pots for biodiversity but also recognised for the holistic and integral part they play in our national identity and the food we produce.

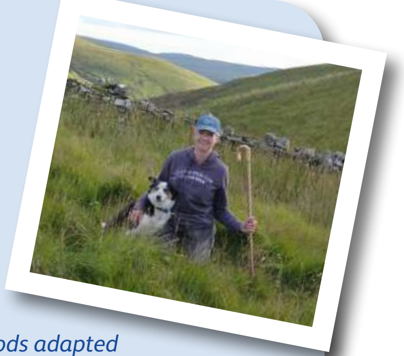
There is a real need to think of climate change and nature recovery not in isolation, but to consider in tandem the protection of natural resources, heritage, rural economies, the health and wellbeing of people, and local food production and consumption. There are opportunities to improve the environment and lower greenhouse gas emissions without compromising food production. After all, this is the foundation of the Paris Climate Change agreement. Yet previous policies have not been holistic in nature and have led to environmental damage in some areas, for example headage payments during in the 1970s, 80s and 90s focusing on livestock productivity alone, leading to overstocking. Without a more complete analysis of UK sheep farming and the positive role it plays in the fight against climate change, the threat of negative results loom.

Sheep farmers deliver for the environment through both a land-sharing and a land-sparing approach, where grazing and farming activity provides for the environment (habitat creation and biodiversity), as well as dedicating specific areas of land for targeted environmental outcomes such as areas of woodland, peatland, hedgerows, scrub and water bodies. Sheep farms of the future are likely to have a spectrum of land management approaches dependant on the objectives and value of that land, from a focus on productivity to a focus on the wider environment and with a range of different levels of balance in between.

Farmers must be engaged in conservation works but need to benefit financially from these actions to ensure productive and efficient food production alongside providing for nature. There is a critical need for food production to be seen as a public good in the eyes of both decision-makers and consumers. There is a case for appropriate incentives for different approaches – the contribution to food security is one level but the contribution to the local rural economy of someone with a farm shop selling specialities and food with provenance has wider benefits for society.

NSA is confident that its approach to multi-functional land use, while focusing on improved sheep health and productivity within established sheep farming systems, is correct and in line with policy thinking. There is an importance of awareness and acceptance of the challenges as a precursor for taking ownership and therefore, being more likely to do the right thing, benefiting both businesses and the targets set out within Government. Looking at sheep farming through a holistic lens ensures the true multifunctionality of sheep farming is represented, reducing the risk of alternative land use strategies becoming a reality.

CASE STUDY: **Lorraine Luescher**



3,000 ewes in a hefted upland system running over 5,400 acres of Scottish hills

Good use of preventative medicines and utilising traditional farming methods adapted to modern challenges ensure excellent flock health and welfare for hill farmer Lorraine.

"I run hefted hill sheep flocks with an emphasis on high welfare. This type of extensive grazing system is the ultimate sustainable farming solution for less productive ground with benefits to landscape, habitats and biodiversity and to economic activity often in remote areas," explains Lorraine.

Flock management focuses on high welfare and disease prevention, replacing ewes from homebred sheep to ensure hardy genetics and inbuilt immunity to ticks.

"Sheep scab is endemic in many hill areas and is a constant threat. Identifying health issues such as OPA is an important part of what we do and ensuring correct nutrition and mineral balance are also key," adds Lorraine.

Low impact grazing assists delicate plant species as well as soil preservation supporting carbon storage and well-maintained stone walls providing valuable nesting habitats and sheep shelter. "The practice of hefting sheep has been used for centuries, however the proactive approach to flock health and welfare is what singles my system out," she says.

"Change of land use to forestry and rewilding are threatening the hill livestock sector. We need better political recognition and financial reward for the public goods – food, climate and nature – delivered by livestock farming."

CHAPTER 3.1

Positive attributes: Trends in sheep carbon footprints

Sustainability extends far wider than greenhouse gas emissions, or even carbon footprints, yet global concerns over climate change have made these the primary focus for government, supply chains and consumers.

It's therefore surprising there is relatively little current information on the carbon footprint of UK sheep production. For example, data quoted is often based on global averages rather than UK specific farming. The media often quote a carbon footprint of 23.7-60.2kg carbon dioxide equivalent (CO_2e) per serving of lamb (the highest of all the foods examined saved for beef and dark chocolate) but analysis was based on lamb data from Swedish, Australian, Sardinian and Irish systems. This has the potential to mislead the reader by suggesting sheep systems across the world are equal in efficiency, productivity and environmental responsibility, and makes it impossible to make evidence-based decisions.

Carbon footprints of sheep production vary considerably across the globe (Table 1) with greenhouse gas emissions per kg lamb liveweight tending to be higher in extensive systems in the global south (e.g. sub-Saharan Africa and Latin America) than Western Europe and Oceania.

Similar variation is also seen within the UK, with results varying according to region, sample size and methodology. For example, in a study of just two Welsh farms, reported carbon footprints of 1.3-143.5 kg CO_2e per kg liveweight depending on the farm analysed and the resources included within the analysis.

Current carbon footprint values for sheep production systems can be derived from one carbon footprinting tool at 29.22kg CO_2e per kg deadweight (~14.3kg CO_2e per kg liveweight) for crossbred ewe flocks and 29.89kg CO_2e per kg deadweight (~14.7kg CO_2e per kg liveweight) for early lambing ewe flocks. Despite these values being lower than many of the global values in Table 1, it has been concluded that emissions per ewe increased between 1990 and 2018 in Scottish sheep production systems as a result of moving towards bigger breeds and heavier slaughter weights.

CASE STUDY: **Hayden and Melissa Wooley**

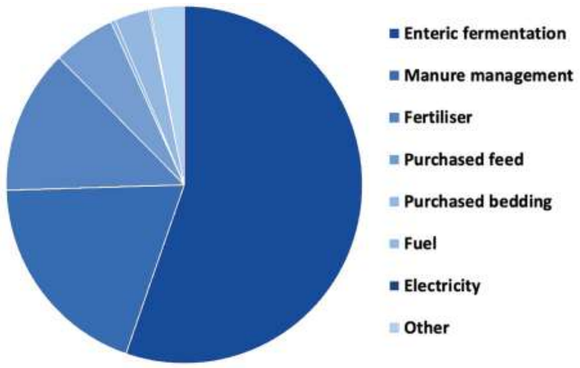
4,000 wool-shedding ewes on 450 owned acres and 1,250 rented acres in Shropshire

Using genetics to remove labour, increase efficiency and ultimately lower emissions is the driving force behind innovations being implemented by Hayden and Melissa.

Melissa says: "We have imported genetics and embarked on progeny testing with a view to improving flock efficiency. Portable accumulation chambers are used annually to test lambs for methane efficiency alongside embryo transfer to accelerate genetic gain. Methane per kg of lamb sold is a good measure of overall flock efficiency and we hope to produce animals with 35-40% lower genetic emissions within just five years. We aim to further compliment this gain with better nutrition and improvements recommended by Defra's Animal Health & Welfare Pathway increasing productivity."

This approach to flock genetics is expensive but Hayden and Melissa have recently been awarded a Farming Innovation grant and they believe the need for further financial efficiencies on farm alongside changing consumer demand will encourage more farmers to change their practices in time. At present their whole farm sustainability strategy includes solar panels, biomass heating, environmental stewardship, hedge planting, herbal leys, cover crops and direct drilling.

Crossbred ewe carbon footprint[12]



Although emissions from UK sheep production declined between 1990 and 2009, primarily as a result of reduced stock numbers, the annual Agri-climate report produced by Defra also concluded that both emissions intensity and total emissions from UK sheep production remained stable since 2009. This contrasts with beef, dairy and pig emissions, which have all declined. UK sheep producers are therefore likely to come under increasing scrutiny and will need to demonstrate clear dedication to reducing greenhouse gas emissions.

In terms of overall greenhouse gas emissions, we know methane is by far the greatest contributor in largely grazed sheep systems. Whether or not you accept that enteric methane is really responsible for global warming (given that from grazed animals it has been part of a natural gaseous cycle for hundreds and maybe thousands of years) it's also right that reducing methane emissions could reduce greenhouse gas emissions overall and help control the climate.

Examining sheep operations worldwide, enteric methane has been shown to represent the greatest proportion of greenhouse gas emissions, ranging from 40-87% of emissions, with manure deposition next, followed by fertiliser and feed. A study of Scottish lamb production also cited enteric methane as the highest contributor to greenhouse gas emissions at 78%, followed by manure methane at 10%[13]. An example carbon footprint for a crossbred ewe flock is shown in Figure 1 and shows a similar pattern – that the major sources of greenhouse gas emissions within the carbon footprint of UK are enteric methane, manure management and fertiliser, with lesser contributions by purchased feed, purchased bedding, fuel, electricity and other sources (crop residues, lime, transport and waste)[12]. Although individual farm footprints will vary considerably, these proportions are relatively constant across operations. Therefore, focusing on reducing emissions from the first three sources should have a greater impact than, for example, investing considerable time or effort reducing emissions from electricity.

Although now rather dated, a study from 2009 showed the carbon footprint of lamb production varied according to system – hill flocks had a carbon footprint averaging 13.61kg CO_2e per kg liveweight (27.78 kg CO_2e per kg deadweight at a killing out percentage of 49%); with equivalent values for upland flocks of 11.05kg CO_2e per kg liveweight (22.55kg CO_2e per kg deadweight) and lowland flocks of 11.08kg CO_2e per kg liveweight (22.61kg CO_2e per kg deadweight). These differences between systems are not unexpected as lowland farms tend to have improved pasture and forage quality and a milder climate, which facilitates increased daily liveweight gains and reduced age at slaughter. Carbon footprints should not be used to penalise or praise individual farms however, but instead to provide a benchmark by which to measure future improvement.

STRATEGIES TO REDUCE GREENHOUSE GAS EMISSIONS FROM UK SHEEP SYSTEMS	
PRODUCTIVITY	Finish lambs earlier. Lamb ewes younger. Improve ewe longevity. Minimise mortality.
GENETICS	Select for low methane emissions. Select for optimal litter size.
FEED CHOICE	Byproduct feeds. Supplemental feed. Feed additives (e.g. seaweed).
PASTURE	Multispecies swards. Rotational grazing. Integrate grazing into arable rotations.

The extent that any sheep enterprise can reduce greenhouse gas emissions depends on the baseline and the degree to which mitigation measures have already been implemented which, somewhat ironically, means producers in the top 25% have less potential to mitigate emissions than the bottom 25%.

Mitigation measures must be applicable to the farm situation, result in an improvement (or at least no change) in economic viability and should ideally be additive, with positive impacts on several metrics or enterprises across the farm, without significant negative trade-offs.

Strategies will vary and aren't necessarily based on farm size or type, but revolve around efficiency. Optimising nutrition, grassland management, genetic merit and animal health could all reduce emissions. Reducing the number of unproductive animals and achieving target weights faster, so stock is on farm for less time, will result in lower emissions of methane and nitrous oxide. It can also free-up land as less is required to maintain current level of output, leaving more for other offsetting strategies such as agroforestry. Given that some emissions are unavoidable, offsetting will play an important role.

Significant greenhouse gas emissions reductions may be achieved by meeting or exceeding the example key performance indicators shown in Table 2. These include, for example, improving lamb growth rate to reduce age at sale or slaughter, enhancing carcase confirmation, increasing the numbers of lambs weaned per ewe, lambing ewes at 12 months of age to maximise productive life, optimising culling rate to reduce the number of ewe lamb replacements required, and improving feed efficiency.

Fewer days on farm means lower emissions, but this needs to be balanced with feed inputs. Ruminants can utilise a range of feeds and forages, and strategic use of home-grown or bought-in feeds can be justified if it cost-effectively accelerates gain. There is also the trade-off that reducing days to slaughter may reduce carbon footprint of the farm – but it is not that simple. For example, reducing days to slaughter would increase peaks and troughs in lamb production out of season, it could affect consumer preference on taste and quality, and potentially reduce diversity of sheep breeds.

Further gains may be achieved by implementing management practices and strategies to improve efficiency and maximise output per unit of input, as shown in Table 3. For example, strategies that improve productivity (e.g. supplemental feed, improved pasture, use of multi-species swards and rotational grazing) tend to improve output and reduce greenhouse gas emission intensity, whereas specific byproduct feeds or feed additives can reduce the greenhouse gas emissions associated with feed choice or have direct impacts upon rumen methane production.

Improving livestock health can also significantly improve greenhouse gas emissions from sheep production. For example, it has been demonstrated that eradicating parasitic gastroenteritis (PGE) in sheep would considerably reduce greenhouse gas emissions from Scottish lamb production.

Research has repeatedly demonstrated that greenhouse gas emissions can be considerably reduced through better livestock management. For example, the Net Zero & Livestock: Bridging the Gap report, showed that innovations across health, genetics, nutrition, waste and land management all provide opportunities for sector-wide emissions reductions and sustainable food systems.

It is known improved health leads to reduction in waste, productivity gains and lower carbon footprints, as well as more responsible medicine use. UK standards of environmental legislation, animal welfare, employment rights are all accepted as being world leading, demonstrating the holistic quality of our food.

But, given the limited published data available, it can be difficult to predict which strategies will have the greatest impact on individual farm greenhouse gas emissions. Given the lack of carbon footprints in the public domain, several meat processors have launched studies to gather primary (farm-level) data on greenhouse gas emissions, which should provide the industry with a greater understanding of the factors that affect emissions from sheep production.

These large-scale datasets will be crucial for identifying specific tools, management practices and key performance indicators that can be leveraged to reduce emissions on both a sector and individual farm basis. The AHDB baselining pilot, for example, aims to secure 170 farms of differing types to collect data over a five-year period in order to track, in detail, the progress of these 'proxy farms'.

Table 1. Variation in sheep system carbon footprints across the globe

REGION	CARBON FOOTPRINT
SUB-SAHARAN AFRICA	30.5 kg CO_2e per kg liveweight[21]
NORTH AFRICA	27.5 kg CO_2e per kg liveweight[21]
LATIN AMERICA	25.2 kg CO_2e per kg liveweight[21]
SOUTH ASIA	29.5 kg CO_2e per kg liveweight[21]
WESTERN EUROPE	17.6 kg CO_2e per kg liveweight[21]
OCEANIA	15.0 kg CO_2e per kg liveweight[21]
WALES	1.30 - 143.5kg CO_2e per kg liveweight[11]
UNITED KINGDOM	11.05 - 13.61kg CO_2e per kg liveweight[16]

Table 2. Ideal key performance indicators for improving productivity and reducing greenhouse gas emissions from sheep production systems[12,13]

KEY PERFORMANCE INDICATOR	IDEAL VALUE
MATURE EWE LIVEWEIGHT	<80kg
AGE AT FIRST LAMBING	12-24 months
WEANING RATE	>160 %
HOMEGROWN FEED USE PER EWE	As low as possible
PURCHASED FEED USE PER EWE	As low as possible
DAILY LIVEWEIGHT GAIN	>0.45g
AGE AT SLAUGHTER	4-6 months
MORTALITY	<5 %
REPLACEMENT RATE	15-25 %

Table 3. Strategies to reduce greenhouse gas emissions from UK sheep systems[12,24,25]

	STRATEGY	EMISSIONS INTENSITY* REDUCTION	EFFECTS
ANIMAL PRODUCTIVITY	Finish lambs earlier	16-24%	Improved lamb output (if finished weight maintained)
	Lamb ewes as hoggets	9-13%	Improved productive life
	Improve ewe longevity	1-6%	Improved productive life
			Improved lamb output (fewer replacements)
GENETICS	Selection for low methane emissions	8-10%	Reduced methane emissions
	Selection for greater litter size	5-9%	Improved lamb output
FEED CHOICE	Byproduct feeds	Variable	Reduced greenhouse gas emissions from feed
	Supplemental feeds	Variable	Improved growth and reproduction
	Feed additives (seaweed, tannins, etc)	Variable	Reduced methane emissions
PASTURE	Multi-species swards	Variable	Improved livestock growth and reproduction
			Enhanced pasture quality and production
			Reduced worm burdens
	Rotational grazing	Variable	Improved livestock growth and reproduction
			Enhanced pasture production
			Improved soil health and carbon sequestration
	Integrating sheep into arable rotation	Variable	Improved livestock growth and reproduction
			Enhanced pasture production
			Improved soil health and carbon sequestration
			Reduced worm burdens
	Optimal fertiliser use	Variable	Enhanced pasture production
			Improved soil fertility
RESOURCE USE	Optimised fuel and energy use	Variable	Reduced greenhouse gas emissions from fuel and energy
	Optimised bedding use	Variable	Reduced greenhouse gas emissions from bedding
FARM RECORDS	Maintaining accurate records	Variable	Evidence-based decision making
	Examining data and trends	Variable	Identification of farm practices that enhance productivity

* Emissions intensity = Greenhouse gas emissions kg CO2e/kg lamb liveweight or deadweight

CHAPTER 3.2

Positive attributes: The role of UK grasslands in the delivery of public goods

Grasslands have played a pivotal role in supporting agriculture and livestock production for centuries. They are the cornerstone of sustainable sheep production in the United Kingdom, accounting for around two-thirds of the total utilised agricultural area of the UK and thus are the most widespread terrestrial ecosystem in the UK.

Grasslands also serve as the primary source of feed/forage for sheep and other ruminants (mainly beef and dairy cattle). Economically, they provide the cheapest source of feed for sheep, support livestock grazing and facilitate meat and wool production, in turn contributing to rural employment and economic development, and help maintain the cultural heritage associated with sheep farming in the UK.

Aside from their economic importance, grasslands also play a vital ecological role – contributing to, for example, biodiversity conservation, soil fertility, water management and carbon sequestration. They are also of cultural importance as, for example, they support tourism and recreation by creating opportunities for food provenance and food related tourism providing an opportunity to reconnect tourists and visitors to the practical ways in which the landscape and environment is managed. They also enable recreational activities to boost mental and physical wellbeing[29]. In addition, they provide a wealth of history and culture, with many traditional practices, buildings and ways of life maintained by the local people.

Degradation of grasslands over time through poor management can however lead to reduced vegetative and animal productivity, declines in soil organic matter, soil compaction and erosion, and habitat loss.

Biodiversity

Grasslands in the UK encompass a wide range of ecosystems and habitats, ranging from extensive, unimproved upland pastures and lowland semi-natural hay meadows to intensively managed, improved temporary grass leys.

These ecosystems host a multitude of plant and animal species, many of which are of conservation concern. Native grassland plants such as wildflowers, sedges and grasses contribute to the rich biodiversity of these areas, supporting pollinators like bees and butterflies.

CASE STUDY: **Richard Thomas**

250 ewes, cattle, cider apples and solar panels on a 300-acre lowland Herefordshire farm

A desire to change and implement modern practices while adapting solutions to individual situations is how Richard believes farming will continue to thrive.

"Our farm is a more functional ecosystem now. It's a long road though so it will take time for all the benefits to be seen," he says.

On Richard's farm rotational grazing with longer rest periods has increased skylarks; tree planting has improved habitats, shelter and water holding capacity; laying hedges has increased yellowhammer populations; and better parasite monitoring and vet engagement has bolstered animal health alongside responsible medicine use.

He says: "Our sheep are profitable and that hasn't always been the case. As farmers we tend to spend time worrying about what we can't control – weather and policy. Recent rainfall has been unprecedented but mitigation is easy – more trees and hedges for shelter and better genetics for flock resilience. Every farm is different and so are the solutions, but the desire to change has to come from you first. We must find a way to focus on the environment and our farm's social license before legislation makes the changes for us."

Grazing is a common management intervention for maintaining the conservation value of grasslands throughout the UK, in addition to the production of food (and fibre in the case of sheep). Defining and assessing biodiversity is complex due to the broad spectrum of biodiversity and multitude of indicators available and used to assess it.

Biodiversity within agricultural landscapes typically relates to three main functions: patrimonial functions (conservation of landscape aesthetic and threatened species), agronomical functions (soil fertility and nutrient cycling, pollination, pest and disease control) and ecological functions (species habitat and ecosystem resilience).

It's estimated up to 90% of semi-natural species-rich grassland has been lost in lowland UK since the 1940s, due to intensified agricultural production and conversion of this land to either improved grassland or arable. Concerns have also been raised that grazing by sheep reduces the conservation value of pastures more than grazing by cattle. This was particularly the case during the 1970s-90s where headage payments drove an increase in sheep number in the UK, which led to significant over-grazing particularly in hill and upland areas. The introduction of area-based support payments in place of headage payments and decoupling of the common agricultural policy during the early 2000s significantly diminished the economic reasoning behind maintaining very high sheep stocking rates. Fortunately, this has meant the rate of grassland degradation in the UK has significantly slowed since the 1980s.

Although agriculture is often blamed for soil loss, we should not ignore the detrimental effects of areas of building and infrastructure development such as new housing, roads, golf courses, sports grounds and gardens for example on soil structure and health, and to habitats affected by soils.

Grazing is a sustainable and natural way to maintain the health and productivity of grasslands and their associated biodiversity when managed appropriately. Overgrazing generally has a negative impact on grassland habitats and therefore biodiversity. Yet cessation of livestock grazing can also negatively impact biodiversity and reduce the conservation value of grasslands. Positive impacts of sheep grazing on biodiversity include controlling the growth of grasses and preventing woody plants, invasive species and scrub from significantly encroaching on grassland ecosystems (particularly useful in areas unsuitable or inaccessible to cattle or machinery) and carriage and dispersal of seeds across long distances via dung.

FUNCTIONS OF BIODIVERSITY

1. Patrimonial – conservation of landscape aesthetic and threatened species.
2. Agronomical – soil fertility and nutrient cycling, pollination, pest and disease control.
3. Ecological – species habitat and ecosystem resilience.

CASE STUDY: David Attwell

Adviser for the Dartmoor Hill Farm Project developing positive relationships and knowledge in a collectively grazed landscape.

Funding from Our Upland Commons for a Healthy Livestock Project has led David to work with 10 graziers who have access to unimproved moorland across two commons in the Dartmoor National Park.

The work in focussing on keeping sheep healthy while also considering the impact animal medicines have on dung beetles and other important wildlife species. Dung beetles are an important sentinel species, as they form an important part of wider food webs and are a prey species for a number of vertebrates, such as the cuckoo.

David explains: "Working with an entomologist, the graziers surveyed their in-bye land and commons for species diversity three times through the year. There was also a review of farm vet and med records to identify treatment regimes, periods and active ingredients in produces used. In total 7,500 litres of dung was examined and 86,000 dung beetles identified.

"There were 358 dung beetles found per litre of sheep dung , almost double the quantity of moorland ponies (186) while cattle averaged just six beetles. Numbers for the in-bye and commons was much lower than the control (26%) with analysis indicating livestock treatments was the likely primary source of difference.

Data analysis showed that 61% of the species chose their preferred dung more than 85% of the time, 50% of these species exceeded 90% in their preferred choice with sheep dung the highest preference.

"This significant quantitative evidence proves the importance of multi-species multi-season grazing for dung beetle communities and highlighted the role of sheep in supporting four winter dung beetle species in particular," David says, adding that the next step is to collaborate on commons health plans with multiple outcomes.

Sheep are very selective grazers and will tend to target younger plants and flowering plants, and can graze very low to the ground, which can negatively impact plant species diversity[8]. Carefully managing the interaction between sheep and grasslands is vital.

A recent systematic literature review found lower management intensity (i.e., nitrogen input, increasing defoliation frequency and grass renewal) to be associated with biodiversity benefits, however provision of high-quality animal feed was negatively impacted – highlighting that trade-offs exist between the multiple ecosystem services grasslands are expected to provide. Identifying and implementing management practices that help support multiple ecosystem service provision and grassland multifunctionality will be key in the transition towards more sustainable sheep production systems.

A study from New Zealand found that while most of the countries' native vegetation (forest, shrubland, grassland and wetland) was found to be located within public conservation land, but a quarter of the total native vegetation was actually located on sheep and beef farms (with half of this comprising native woody vegetation) – highlighting their important role and the need to support sheep and beef farmers with nature conservation on their farms.

Soil health

The productivity and functionality of grasslands is closely tied to soil quality and fertility, and grazing livestock play an important role in maintaining and improving this. Organic matter and nutrients are returned to the soil via livestock excreta, supporting nutrient cycling within the soil which in turn supports plant growth and regeneration.

The specific impacts of grazing on soil physical, chemical and biological characteristics have mainly been investigated in the context of grazing intensity (low, medium and high-intensity grazing compared to no grazing). A recent global meta-analysis of the impact of grazing intensity on 15 different soil properties found, when compared to no grazing, heavy grazing significantly increased soil compaction and reduced soil organic carbon, nitrate and soil moisture; moderate grazing significantly increased soil compaction and alkalinity and reduced soil organic carbon and total nitrogen; light grazing only significantly increased soil organic carbon and ammonium. The report also found cattle grazing had a higher impact on soil compaction, soil organic carbon and available potassium compared to than sheep grazing. But it is important to note that many other factors such as climate conditions, soil type, vegetation cover and stocking method will significantly influence the impact of grazing intensity on soil properties. For example, topsoil macroporosity density and size was found to decrease under set-stocking whereas stable soil structural conditions were maintained under rotational stocking of sheep over a three-year period.

Carbon sequestration

Grasslands are valuable carbon sinks in the UK. In an era of growing concern about climate change and its impacts, the role of grasslands in carbon storage is increasingly being recognised and appreciated.

CASE STUDY: **Ian May**

450 ewes plus suckler cows on 330 acres of upland and lowland areas of North Devon

Balancing sustainability, realistic expectations and a profitable business are key priorities for Ian.

"It is important farmers demonstrate we are good custodians of the countryside. I want to help show this can be done while producing quality food. I look for easy wins on-farm where it is good for the environment but also good for the business," he says.

Ian is using Countryside Stewardship grants to create and maintain new habitats such as woodland areas and reinstating hedgerows to divide fields and allow increased rotational grazing to improve soil health, along with herbal leys, potentially allowing for a reduction in fertiliser use.Already Ian is seeing benefits in biodiversity.

Using increased faecal egg counts and working closely with his vet should improve lamb growth rates and promote responsible medicine use, improving animal health, reducing costs with knock-on sustainability benefits.

"The system needs to fit in with individual circumstances and constraints – farm size, weather, soil type, finances and staff willingness. I'm a strong supporter of peer-to-peer learning, especially with the proliferation of new schemes. Go and talk to your neighbours, see what they have done and how their actions can be applied to your situation," he says.

The UK was one of the first countries to introduce legislation to deliver net-zero greenhouse gas emissions by 2050. Net-zero is defined by the Intergovernmental Panel on Climate Change (IPCC) as the point at which 'anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals'. Carbon sequestration in soils is defined as the process of transferring CO_2 from the atmosphere into soil via plants, plant residues and other organic solids (such as manure) and retaining that carbon in the soil as part of the soil organic matter.

Globally in 2010, unimproved and improved grasslands were estimated to be storing 53 tonnes/ha and 50 tonnes/ha, respectively, of soil organic carbon in the top 30cm of soil, with an estimated total annual uptake of 63.5megatonnes of carbon. However these soil carbon stocks are sensitive to management and land use change, and the long-term impacts of these on soil carbon can take decades to materialise.

Current literature has found no clear relationship between grazing management and carbon sequestration. Some studies have reported increases in soil organic carbon in response to grazing while others have reported no change or even decreases in soil organic carbon. Factors such as climatic zone (temperature and precipitation), grazing intensity, net forage production, plant species and soil characteristics have all been found to have strong, interactive effects on grassland soil carbon stocks and carbon sequestration.

A recent systematic literature review and meta-analysis of grazing management for soil carbon sequestration in Australia found no significant impact of stocking intensity or method directly on soil organic carbon. However lower stocking intensities and/or incorporating rest into grazing systems (i.e. rotational grazing) had positive effects on potential drivers of soil carbon sequestration such as herbage mass and ground cover, and herbage growth rate and below-ground biomass in some circumstances.

A study from Canada comparing grazed and non-grazed areas of land found the total (above and below-ground) carbon content of long-term light to moderately grazed ecosystems to be 8.5 % higher compared to non-grazed, which was primarily due to increased soil organic carbon and roots in the grazed ecosystem compared to non-grazed.

In the UK, the capacity to make significant gains in soil carbon sequestration may be limited in many agricultural soils, particularly those under permanent grasslands, as they are often likely to be near or at a state of carbon equilibrium. Nonetheless, it is vitally important management practices maintaining and protecting soil organic matter levels and carbon sequestration in grassland soils are sustained. A key example of where sheep grazing may significantly help improve soil carbon sequestration (amongst other important soil characteristics) is through the integration of livestock into arable systems – more on this in chapter 3.3.

Other ecological outcomes

CASE STUDY: **Neil Heseltine**

1,100 acres of owned and rented permanent pasture in the Yorkshire Dales

In 2012, Neil was one of the first farmers to sign up to Pasture for Life, an organisation that champions feeding only grazed and conserved pasture to ruminants from birth to slaughter. He has found this regenerative approach has multiple benefits for the farm and the environment.

Neil explains: "We started by moving the cattle to a more extensive system and learnt a lot of lessons from them. Now we have started with the sheep, reducing numbers significantly from 400, changing the breed from Swaledale to Wensleydale and feeding no concentrates. We avoid using any veterinary treatments unless they are really needed.

"Changing to the Wensleydale helps retain UK flock diversity and their long fleeces also have a value – we regularly earn £50 a fleece. We find the meat is a higher quality too and 100 % grass-fed lamb is known to be healthier for people to eat."

Neil says output has increased (40 % more liveweight per hectare) despite inputs reducing, which means the business is more profitable.

"There are so many other wins too," he says. "There are a lot more native plants and flowers in the sward. This in turn has led to many other elements of nature increasing – from insects, invertebrates and birds. In my mind, this is the most sustainable type of livestock farming there is."

Grasslands are also recognised for their social and cultural significance and can offer a number of cultural ecosystem services such as recreation and aesthetic value, in addition to providing many provisioning, regulating and maintenance services.

How grasslands are managed has a major influence on the variety and combination of ecosystem services grasslands can be provide. Inevitably, trade-offs do exist between particular ecosystem services, but identifying and implementing management practices that synergise and therefore maximise the ecosystem provisioning of grasslands may go some way to contributing functional landscapes, food security and sustainable livelihoods[29].

Grasslands tend to hold more socio-cultural value for rural dwellers compared to urban dwellers, however there is scope to educate the public and, more importantly, consumers on the ecosystem benefits grasslands can provide, in turn ensuring the sustainable management and use of these valuable landscapes.

Due to the interconnectedness between grasslands, sheep farming and the environment, a holistic and sustainable approach to sheep and grassland management is essential, integrating adaptive strategies and innovations. We must recognise the vital role of grasslands and sheep production in supporting the rural economy, delivery of ecosystem services and its cultural value. The ongoing efforts to protect and manage grasslands sustainably are crucial for ensuring the continued success of sheep farming in the UK while preserving the invaluable natural resources that underpin it.

From an environmental perspective, policy across the devolved nations has the environment and nature at its centre, ensuring British wildlife has increasingly improving habitats on land and in our waters. In fact, the success of many of native wildlife lifecycles are directly linked to livestock grazing providing food, nutrients and a favourable environment.

Grass-fed livestock farming in the UK, should therefore be seen as a key contributor to the efforts and indeed a mechanism to reach not just net-zero but also providing additional benefits to meet many more of societies interests encompassing sustainability.

UK climate and weather conditions are perfectly suited to growing grass and forage plants and. even with climate change, grassland plants (both as permanent pasture and short-term leys within a mixed farming rotation) will continue to be one of the most resilient and stable crops/habitats available to us.

Healthy soil is the ultimate foundation of sustainable food production. Given that all the food humans

CASE STUDY: **Sean Jeffreys**

New entrant in a joint venture running 550 breeding ewes on the Black Mountains, Powys

Having established herbal leys for the sheep flock, Sean and his joint venture partners Ian Rickman are focusing on farm infrastructure to facilitate rotational grazing.

Sean says: "Herbal leys are handing in the spring for ewes and lambs, and great for finishing lambs later in the season. They have enough clover in them that they grow without the need for fertiliser so are zero input once they're established.

"Rotational grazing will allow us to better utilise all our grass and grow more, allowing us to increase stocking density in the future. We are also now resting our grassland for at least 100 days over winter, which is achieved through root crops, winter keep, housing and sacrificed ground with bales. It means we grow more grass and quicker in the spring, as the plant has time to strengthen its roots and increase leaf area. Planning is crucial to achieve 100 days' rest, to plant winter crops and secure winter grazing."

Sean says it has been crucial to carry out soil sampling, better use farmyard manure and spread more than 100 tonnes of lime in two years to correct soil pH and get the most of what fertiliser is still bought in.

"The herbal leys have allowed us to remove fertiliser requirements in those areas, and planting red clover leys for silage has allowed us to drastically reduce fertiliser inputs there too," he says. "Not only is it good for the environment but also saving us money. Reseeding silage ground did put some cashflow pressure on, but these will be recuperated in the lowering of winter feed bills and hopefully increased lamb performance."

CHAPTER 3.3

Positive attributes: Feed and land use

consume either originates from the soil (plants and animals) or is affected by soil management (aquatic life), it's essential to maintain and improve soil quality.

Soil contains an astonishing diversity of microorganisms and insects with ecosystems that function through digesting waste plant material, converting inaccessible nutrients into those that can be used by plants, facilitating nitrogen fixation in leguminous plants, and developing a flexible and adaptable soil structure. This allows the soil to withstand mechanical (tillage and grazing), chemical and crop inputs and climatic challenges and, crucially, to hold or release water.

Improving grassland productivity has synergistic positive impacts on sheep performance – introducing rotational grazing and monitoring grass growth using a plate meter or sward stick allowed producers to increase stocking rates and increase grassland utilisation by up to 30% in one cattle study, and similar results would also be expected in sheep systems.

A more intensive form of rotational grazing – mob grazing – consists of sheep grazing small sections of land for a short time before moving to new grass allowing a rest period. This mimics the natural grazing regimes under which many modern grasses evolved, maximising photosynthesis and productivity. Often stocked at a higher rate than conventional grazing systems, mob grazing is considered to reduce selective grazing, improve soil organic matter content and enhance the provision of wildlife habitats.

Grazing sheep play an integral part in soil health through a variety of different yet complementary mechanisms. Manure deposition on soil in well-managed grazing systems has a positive effect upon soil fertility through direct inputs of essential elements (nitrogen, phosphate, potassium and sulphur). The rate of release of these nutrients to both forage and arable crops within an integrated rotation is relatively slower and more constant, compared to inorganic fertiliser application. It may be more difficult to assess the precise quantities of nutrients being returned to the soil from grazing animals compared to manure spreading or inorganic fertilisers, yet regular soil testing and appropriate stocking rates allows nutrient inputs to be benchmarked and regulated.

Sustainable feed use

Whether to provide supplementary feed and the consequent choice of feed ingredients is an important consideration for sheep system sustainability. Compared to pig and poultry systems, feed use contributes a lower proportion of greenhouse gas emissions per kg of lamb at ~5% of the total (see pie chart in chapter 3.1), yet high quantities of purchased feeds can still have a significant effect on emissions. This is a particular issue for feeds containing soya, which often carries a high greenhouse gas emissions cost in carbon footprint tools.

Increasing the proportion of homegrown feeds should reduce greenhouse gas emissions compared to purchased feeds, although this depends on efficient production, using where possible, targeted fertiliser application and minimum or no-tillage systems.

The choice of whether to provide supplementary feed should be weighed against the potential productivity improvements that may be achieved. Using purchased feeds to supply nutrients that are lacking in pasture or homegrown feeds may improve sustainability provided changes in greenhouse gas emissions or resource use are less than the impacts of homegrown feed production, or outweighed by improved productivity. For example, providing supplemental feed to enhance nutrient supply just before tupping or lambing should improve conception and lambing percentage, thereby improving both greenhouse gas emissions and profitability. However, it is not necessarily cost-effective nor environmentally advantageous to increase supplemental feed to finishing lambs so the potential benefits must be weighed against the environmental and economic cost[229]. For example, increasing animal production by feeding more concentrate was less efficient and increased environmental impacts compared to increasing grass production, because concentrate required significantly more resources than pasture to produce and generated more emissions[229].

The environmental impacts of feed production are reduced further by incorporating byproducts of human food and fibre production, such as sugar beet pulp, maize gluten or rapeseed meal, into the ration. These human-inedible feeds carry a lower environmental burden than the crops they are associated with, as the majority of resource use and emissions are attributed to the main crop.

This is another advantage of integrating sheep into the arable rotation, as straw and vegetable byproducts can be included in the ration. Byproducts from horticulture have also been trialled as a potential diet ingredient and replacing a concentrate mixture with fruit or vegetable byproducts from horticulture has also been shown to maintain ewe performance while reducing greenhouse gas emissions and water consumption.

Feed efficiency is also a key consideration in sustainable feed use , as breeding sheep with an improved feed conversion should reduce both feed and land use as well as lending further ammunition to the debate over feed-versus- food. It's often suggested improving feed efficiency will also reduce enteric methane emissions, as it means a greater proportion of energy is used for performance rather than lost as methane, however this concept has recently been questioned.

Nevertheless, given enteric methane is the highest contributor to the carbon footprint of sheep operations, feed ingredients that reduce methane output while at least maintaining performance should improve sustainability.

Condensed tannins, essential oils and seaweed have all been used to reduce methane emissions, although results have been inconsistent and not all products are commercially available . The new feed additive 3-nitrooxypropanol (3-NOP) also appears to show consistent effects in reducing methane emissions and has been approved for use in dairy cattle in the UK, however, it is not yet available for use in sheep.

There is also some debate as to how feed additives may be applied to sheep production. Although they can be incorporated into the diets of finishing lambs or other supplemented sheep, they tend to work better at a consistent feeding rate so may be unsuitable for pasture-based systems. Feed additives are therefore a useful tool in reducing emissions but should not be considered a silver bullet for all systems.

Integrating into arable

It is clear converting grassland to arable has negative impacts on the diversity of important soil microorganisms, and reversion back to grassland, although beneficial, does not completely reverse changes in the soil microbiome. Inclusion of a well-managed grazing ley, cover or fodder crop in the arable rotation would therefore be expected to confer some benefits.

Integrating sheep into arable rotations is not a new or modern technique. It was employed across the UK, with particular focus in Norfolk, and known as 'sheep-corn husbandry' in the seventeenth and eighteenth centuries. Nevertheless, with increasing specialisation and regionalisation of farming systems, sheep and arable enterprises were often disconnected until

CASE STUDY: **John Pawsey**

1,000 New Zealand Romneys integrated into a large organic arable enterprise in lowland Suffolk

Concerted effort over 10 years has seen John lift the soil organic matter on his arable farm from 2.9% to almost 6%, mainly through the inclusion of grass leys and grazing sheep in the arable rotation.

He says the impact on biodiversity has been incredible. "In 1999 I adopted organic practices and added green manures sporadically as I went along. It was when the sheep arrived on the farm in 2014 that the flies and dung beetles seemed to appear instantly. Bird species have thrived and species like lapwings, yellow hammers and linnets all come straight for the sheep pastures.

"I'd say the birdlife has increased mostly due to the sheep, as sheep provide an area where they can land, nest and scavenge at times of the year where they can't get into the arable crops. Sheep dung and flies provide insects to feast on too."

John is very proud of the progress he has made on both soil health and biodiversity, but says the change has not been without challenges and continues to be a learning curve.

"The best method is learning from your own mistakes and from other farmers trying to integrate organic and/or regenerative principles into their systems. To increase adoption, I'd advocate for farmers to see it in action by visiting farmers who are doing it. They wouldn't open their gates if they weren't doing it well or proud of their achievements. I've been doing this a long time but I know there is always more to learn and the best way to do it is by asking those who are already doing it."

relatively recently, when their benefits gained greater appreciation.

Sneessens et al. modelled the impacts of mixed crop/livestock systems in French farming systems at two different levels of integration (80:20 or 20:80 crop to livestock) and showed contrasting yet positive impacts of integration compared to crops or livestock alone. The 80:20 crop to livestock system had a 44 % increase in farm income, 18 % gain in livestock production and 14 % decrease in cropping greenhouse gas emissions; whereas the 20:80 crop to livestock system had a 53 % improvement in nitrogen balance and a 9 % decrease in energy use for livestock production.

Sheep can also be used within viniculture systems to improve overall productivity and reduce the need for chemical weed or vegetation control, which has been adopted in a UK vineyard in Essex. A study of French and German wine producers who used sheep to graze the vineyards cited improvements in resource conservation, vegetation control, soil fertility and biodiversity, as well as a preventative role against soil erosion.

The homogenous landscapes commonly present in arable systems have been associated with reductions in biodiversity, hence interest in maintaining uncultivated field margins and hedgerows. Incorporating a well-managed grazing system into the rotation therefore has the potential to improve biodiversity, providing the stocking rate is suited to the available resources (intensification tends to have negative effects upon biodiversity) and sheep are temporarily removed at times when grazing could have significantly deleterious effects, for example when plants are flowering and therefore at their peak potential for attracting insects.

Sheep tend to have fewer negative impacts on soil structure from treading or trampling than cattle, largely as a function of their different grazing behaviour and lighter weight. Indeed, comparing the effects of a single severe or repeated grazing event by cattle and sheep on pasture health showed cattle had a greater negative impact than sheep when stocked at the same metabolic liveweight per hectare, although sheep grazing led to greater compaction than cattle grazing.

Operating a mixed grazing system, either alternating or combining cattle and sheep grazing may provide further opportunities for improved productivity and enhanced ecosystem health. In a global meta-analysis of the literature, d'Alexis, et al. reported that mixed grazing systems improved liveweight gain per hectare by 28.6 % compared to sheep alone and by 25.1 % compared to cattle alone, although the daily liveweight gain per species was 40.7 % lower for sheep and 32.3 % lower for cattle than the gain when reared alone.

Within the UK, Fraser et al. compared sequential sheep

CASE STUDY: Perry Parkinson

First generation farmer managing commercial ewes over 750 acres of arable and grassland in lowland Stirlingshire

A trip to New Zealand - funded by the NSA Samuel Wharry Memorial Award - where he witnessed the negative effect of resistance by sheep worms to anthelmintic treatments inspired first generation farmer Perry Parkinson to change his own farming practices.

"By implementing all our management decisions in conjunction with working alongside the arable enterprise, we have really cut down our anthelmintic use and are already seeing the benefits," says Perry, explaining that reduced use of worming products reduces the speed at which resistance develops.

The farm carries out regular faecal egg count testing, rotates stock on clean reseeds behind cereal crops, carefully chooses anthelmintics depending on the time of year and selects stock that is more resilient to worm burdens. As a result, no anthelmintics are now used on ewes, lambs are reaching their target weights quicker and there are fewer instances of high worm burdens in lambs.

"We're not only reducing additional costs on farm, but reducing the amount of chemicals expelled in sheep dung, reducing the rate at which resistance develops and putting goodness back into arable rotations, which in turn reduced the need for chemical fertilisers. Herbal leys and legume crops are naturally fixing nitrogen back into the soil free of charge," says Perry.

and cattle grazing systems and found lambs grazing plots previously used for cattle and sheep grazing together had a greater daily liveweight gain than lambs grazing sheep-only grass plots. Similar changes in productivity per unit of land area were reported by Fraser et al. by incorporating cattle into sheep-only grazing systems, with additional benefits gained from increases in both butterfly and bird species richness. Furthermore, Su et al. revealed that mixed sheep and cattle grazing systems improved sward density and enriched insect biodiversity within the grazing area.

Integrating sheep and arable enterprises by incorporating pasture and fodder crops into the arable rotation may have synergistic benefits to whole system productivity that outweigh the performance of the individual operations. Soil under grass or fodder crops tends to be less susceptible to erosion, not least because of a lesser rate of tillage operations than in arable crop production, which may lead to synergistic benefits for later arable crops.

Although concerns over grazing-induced soil compaction potentially reducing arable yields have been reported in some regions, this may be alleviated either by restricting stocking rates or accounting for increases in whole system productivity, rather than arable-alone.

Farmers are increasingly aware of the benefits of good soils and the need to manage them accordingly, seeing improved overall biodiversity; flood and erosion mitigation; increased crop yields, better animal health and welfare; a reduced need for artificial fertilisers and therefore less pollution and carbon emissions; and enhanced nutritional value of food produced. However, due to the cost of rectifying degraded or acidic soils that have been out of production or intensively farmed, those on short term leasing agreements cannot afford or will not reap the benefits from[75].

Carbon sequestration is a major sustainability benefit of integrating sheep into the arable rotation, although the degree to which carbon can be sequestered depends on previous soil management, stocking rate and soil type (discussed in chapter 3.2).

Long-term (70 year) experiments have shown increases in the organic carbon content of topsoil conferred by including grazed grass/clover leys into the arable rotation, although these increases only continued until the soil reached an equilibrium point and did not continue indefinitely. Nevertheless, the increase in soil carbon was considerable compared to losses over the same time period from all-arable cereal or root crop rotations.

Grazing sheep on clean pasture is a demonstrated control strategy for controlling parasite loads and, by extension, reducing the need for parasiticides, which can have significant negative impacts on biodiversity when expelled from the animal via its dung. Non-chemical control mechanisms, including arable rotations that allow for sufficient time between grazing periods, may therefore facilitate better gastrointestinal parasite control.

A study into lamb performance in different Brazilian integrated crop-livestock systems found 300-day gaps between grazing periods produced clear pasture, with lambs reintroduced to the clean pastures having progressively declining levels of gastrointestinal parasites.

Introducing grass or herbal leys into an arable rotation can provide a holistic method of weed control, with grazed cover crops providing a physical barrier against weed emergence, although the degree to which weeds are controlled may depend on rotation characteristics and management.

Furthermore, leys often provide an unhospitable environment for weeds due to competition for water, nutrients and light; may compromise weed growth through cutting for hay or silage; have lower nitrogen

Table 4. Benefits of livestock in arable rotations

FOR SHEEP

- Nutritional benefits of diverse swards.
- Improved liveweight gains from clean grazing.
- Additional grazing opportunity.
- Anthelmintic benefits of diverse forage/clean grazing.
- Outwintering to reduce housing costs.
- Opportunities for new entrants.

FOR ARABLE

- Improved soil health.
- Additional income opportunities.
- Better crops in subsequent years.
- Reduced mechanical mowing.
- Weed control.
- Environmental payments.

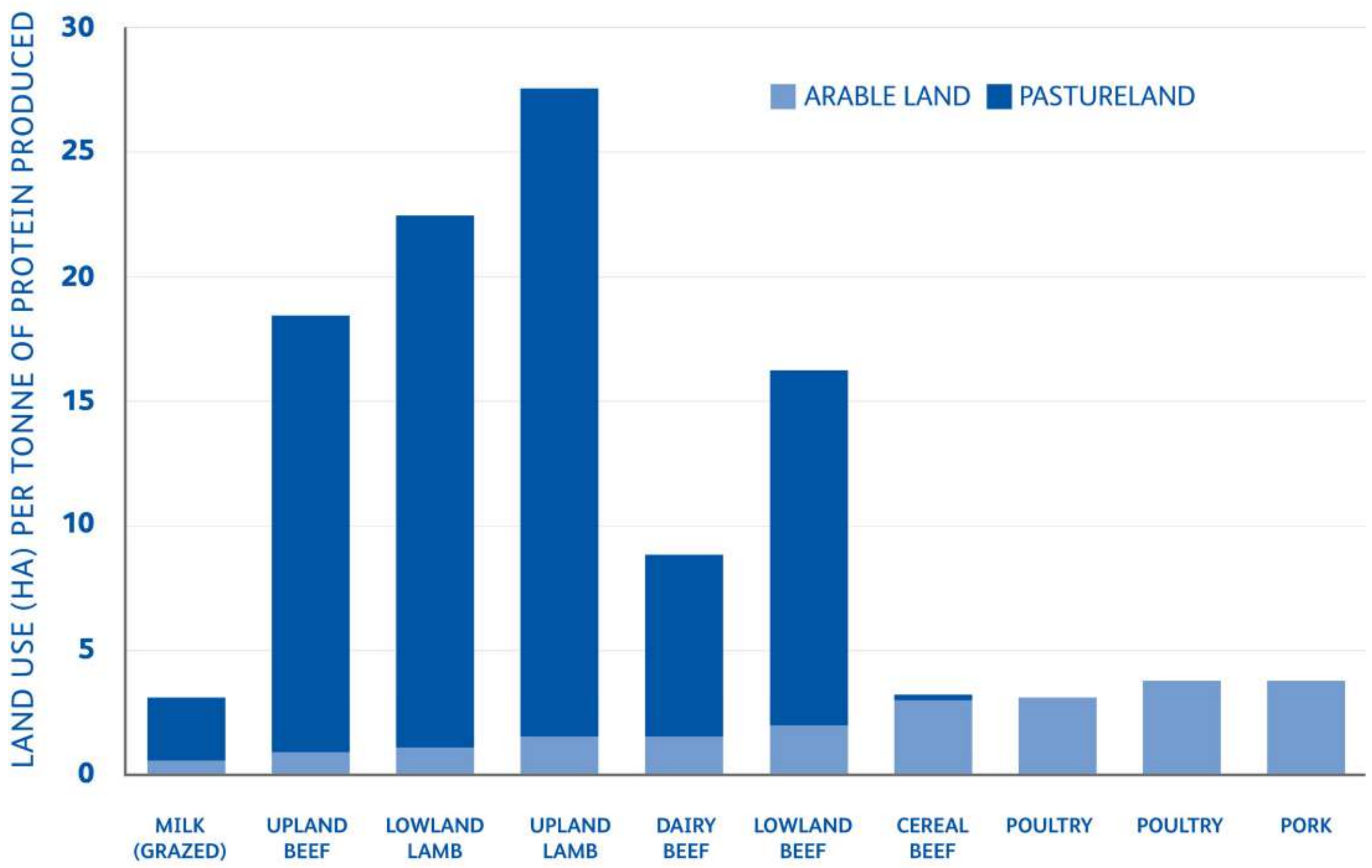
FOR THE ENVIRONMENT

- Ecosystem enhancement.
- Increased yields.
- Increased biodiversity.
- Reduced flooding / buffer against drought.
- Carbon sequestration.

applications which may reduce growth in species with a high nitrogen requirement; and, in some species (including lucerne and bird's-foot trefoil) may release specific compounds that inhibit weed growth. Some plants species also offer anthelmintic properties due to a high level of tannins when consumed and through their physical structure inhibiting larval movement.

It's worth remembering the economic aspect of sustainability is still a vital consideration for all sheep production systems. Although sheep integration provides a range of benefits for arable farmers, the introduced cover crops or leys must be profitable in their own right or improve whole farm financial viability to ensure the balance between economic, environmental, health and social factors remains stable. Increasingly some of the cropping options that can support the integration of livestock enterprises are also eligible for public good reward payments due to their environmental benefits.

Figure 2. Pasture and arable land required by different UK livestock systems per tonne of protein produced. Adapted from Wilkinson & Lee



CHAPTER 3.4

Positive attributes: Trees, hedges and woodland

Approximately 30-50 % of countryside trees outside of woodland have been lost over the past 150 years, with an estimated 50 % of hedgerows having been removed from agricultural land since the 1940s because of the intensification and mechanisation of farming, especially arable farming.

Tree planting is an important tool for the UK to help meet its pledge of reaching net-zero greenhouse gas emissions by 2050. The UK's sixth carbon budget calls for an additional 440,000ha of mixed woodland to be planted by 2035, which would see the UK's overall woodland cover increase from 13 % to 15 %, with further ambitions to increase this to 18 % by 2050.

Tree planting is also an important tool for off-setting the greenhouse gas emissions arising from sheep production to lower carbon footprints at an individual farm level, as well as whole-industry level, as carbon sequestration into soils alone will likely not be sufficient to balance sheep production greenhouse gas emissions.

However, tree planting is not the only tool and the value of grasslands and their multifunctional resilience must be recognised, removing the either/or debate over carbon capture but seeking multifunctional resilient landscapes that include pasture, trees and hedges, each with their own carbon value.

Taking land out of agricultural production to achieve these tree planting targets creates a potential conflict between land use to produce food/fibre and land use for carbon sequestration. Tree planting may also pose a threat to the biodiversity and other ecosystems services that grassy-biomes provide, particularly in the case of natural, semi-natural and improved low-input grasslands that still exist in many parts of the UK.

Furthermore, afforestation of grasslands using flammable plantation trees could also increase the risks associated with wildfires, by shifting the fire type from lower intensity grass-fuelled fires to high-intensity crown fires.

There are two main routes to increase tree cover and woodland area on agricultural land – either via afforestation whereby grazing livestock are excluded from wooded areas; or via agroforestry practices whereby grazing livestock and trees are integrated with one another, for example via wooded pastures, silvopasture, hedgerows, shelterbelts and row systems.

INTEGRATING TREES ON FARM

There are two main routes to increase tree cover on agricultural land

1. Afforestation whereby grazing livestock are excluded from wooded areas.
2. Agroforestry whereby grazing livestock and trees are integrated with one another, for example via wooded pastures, silvopasture, hedgerows, shelterbelts and row systems.

Historically, the approach to trees/forestry and farming in the UK has been very siloed, driven by schemes such as the Forestry Commission's compulsory land purchase programme for forestry creation to increase timber production in the UK following the first world war, and the common agriculture policy (CAP) which has, until very recently, disincentivised the planting of trees on productive agricultural land.

Despite this, practices that integrate livestock production with trees are still somewhat common in many Mediterranean countries, particularly Spain, Greece, France, Italy and Portugal, but is very rare in the UK with only 2.2 % of the total terrestrial area of the UK under any form of livestock agroforestry in 2012.

However, it is becoming increasingly apparent the combined benefits from integrating trees with livestock production are likely to outweigh the benefits of each in isolation. The ever-increasing demand for food, feed, fibre and fuel is placing increasing pressure on land, which globally is a finite resource and is at serious risk of decline as the impacts of climate change take hold. As such, multi-functional land use and management practices that go beyond just focussing on primary production are becoming increasingly sought after.

Data from the James Hutton Institute's Glensaugh Agricultural Research Station, which is situated on severely disadvantage agricultural land around 56km south-west of Aberdeen, has shown silvopastoral systems of up to 400 trees per hectare planting density are able to maintain a similar level of sheep grazing and productivity to a pasture only system, while also achieving a similar carbon sequestration level to land that is 50 % forested.

Similarly, results from a silvopastoral experiment in North Wales found the presence of trees did not affect livestock productivity in the first six years of establishment and the planting of trees in clumps (at 400 stems per ha) appeared to provide the best combination of benefits in terms of tree growth/diameter alongside maintaining livestock productivity.

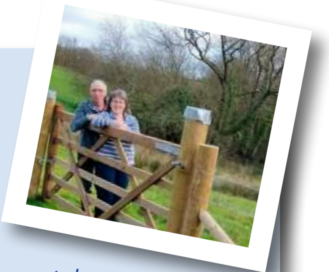
Aside from carbon sequestration and storage potential, tree planting can also benefit sheep welfare by providing shelter and shade from adverse weather. Providing shelter during lambing time has been shown to improve neonatal lamb survival by up to 37 % for twin lambs. Reducing wind-chill effects experienced by sheep through shelterbelts and windbreaks may also benefit productivity by reducing energy lost through thermoregulation.

Frther investigation of the synergies and trade-offs between agroforestry and livestock productivity is required as studies that include measures of livestock productivity are currently lacking, particularly in relation to temperate agroforestry systems.

Fodder from trees can also be used to feed livestock including sheep, a practice common in tropical regions but less well studied in temperate regions, where sheep are mainly fed grazed grass, silage and hay. A recent study of willow, oak and alder in the UK found the leaves of these tree species to contain sufficient metabolisable energy and crude protein to exceed the nutritional requirements for growing lambs. However, micronutrient provision to livestock was much more variable between tree species, with willow exceeding zinc and cobalt requirements while alder and oak either met or were below the recommended levels[111].

Tree fodder tends to also be a good source of secondary compounds such a condensed tannins, which have been shown to increase rumen bypass protein, prevent bloat, provide anthelmintic effects and lower methane and ammonia emissions.

CASE STUDY: **Bryan and Liz Griffiths**



750 breeding ewes plus fattening cattle on a 320-acre lowland farm in North Devon

With a growing awareness of environmental responsibilities and a desire to reduce overgrazing, Bryan and Liz have utilised government funding to enhance biodiversity and work more closely with nature.

"We have divided large fields, created new hedgerows and fenced off less productive areas to increase wildlife habitat," explains Bryan. "We have also been maintaining and increasing the diversity in grass swards and reducing overgrazing and poaching through more rotational grazing instead of set stocking."

The couple have seen an increase in flora and fauna, less soil run off and a reduction in the use of chemical fertilisers using their new systems – but have had to manage the financial implications carefully.

"One challenge to changing our land management is understanding the financial impact of any proposed actions, such as reduced stocking rates and reduced inputs," says Bryan. "Liz and I believe information should be easily available to farmers considering a more sustainable approach to their farming. Local, facilitated discussion groups to disseminate information on environmental and funding opportunities would be a real asset to encouraging more of us to adopt environmentally beneficial practices."

The presence of trees can also help protect soil from erosion and improve water infiltration and water holding capacity, in turn helping reduce surface runoff and having the potential to mitigate flood risk . While there is some evidence of the flood risk mitigation potential of carefully planned and managed woodlands in the UK, this evidence base is somewhat sparse[117], particularly in the context of livestock agroforestry systems as much of the work to date has focussed on comparing an ungrazed wooded areas to unwooded grazed pasture.

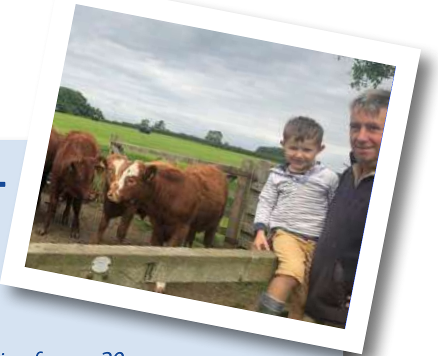
Establishment of trees on sheep farms does require careful management, particularly in the first few years after planting as sheep can damage tree stems, roots and ground vegetation due to their natural behaviour to browse and rub. Saplings and young trees therefore need adequate protection and constant monitoring if integrating with sheep grazing to ensure successful tree establishment. Careful consideration also needs to be given to the type(s) and species of tree to plant, planting design and density.

Tree planting also offers an opportunity for additional business income from timber production or fruits. However there is a long lead-in time before this income can materialise (at least 20-25 years for tree species that are typically used for timber).

Productive land should not be sacrificed for net zero efforts such as blanket forestry – the right tree and the right ambition must be in the right place. Active farmers need incentives and reward for sequestering carbon on farm and, where possible, encouragement to consider renewable energy production options.

These measures, along with tempering rampant enthusiasm for planting our grasslands with trees, would mean UK sheep farmers may not just find net zero achievable, but deliver on a more far-reaching assessment of sustainability.

CASE STUDY: **Mike Adams**



300 ewes on a 325-acre lowland beef, sheep and arable unit in Rutland

Having started as a first generation farmer 20 years ago, Mike's newest self-set challenge is agroforestry planting five alleys of broad leaf, fruit and nut trees, including hazel for coppicing.

"I decided to implement this system following trips to Europe with an Erasmus project NSA was involved in. I saw the impact agroforestry had on farms where climate extremes are far worse than in the UK," explains Mike.

"We haven't seen the full benefits yet, as the trees were only planted last winter. However, there are already noticeably different insects visible in the alleys. Even the tubes and guards are slowing the winds down, so they will definitely provide beneficial shelter and shade in a few years' time. Tree alleys make a great template for mob grazing."

Mike is already planning further planting with browsable willow and more cropping trees, but admits this wouldn't work well for all farms.

"It's a long-term project which would be a challenge on tenanted land. Our fruit trees will be six or seven years until full production, which wouldn't work on the land we have on a five year farm business tenancy agreement" he explains.

He is hoping funding for similar projects under the government-funded Sustainable Farming Incentive will tempt more farmers to consider agroforestry and, in time, there will be more published case studies showing the benefits of such schemes.

CHAPTER 3.5

Positive attributes: Health and welfare credentials

The UK sheep industry is governed by some of the strictest regulations, resulting in it having among the highest agricultural standards of any farming nation across the world.

In the area of health and welfare, sheep farmers have increasingly worked hard to achieve this through proactive flock health planning that leads not just to improved health and welfare, but efficiency, environmental footprint, and job satisfaction.

NSA has long promoted the importance of the health of the national flock and much of the association's work encourages farmers to implement a range of preventative measures to ensure a healthy, productive flock at the foundation of profitable and sustainable business.

In the UK, there has been a significant interest in the health and welfare of farmed livestock with 86% of consumers agreeing the welfare of animals is important to them when purchasing products and 79% of British consumers believing the UK has overall high welfare standards.

Governments aim to uphold this through regulations, with the Animals (Penalty notices) Act 2022 being set up to penalise those who are non-compliant with animal health and welfare regulations. Voluntary assurance schemes and codes of practice provide farmers with high animal welfare standards to adhere to, aligned to aspects of husbandry and management, such as housing and transport, use of medicines and greenhouse gas reduction.

According to Fernandes et al. many consumers perceive that those caring for farm animals should make necessary changes to animal welfare, irrespective of the cost, but the associated costs can temper improvements that can and cannot be made.

CASE STUDY: **Pauhla and Martin Whitaker**

310 organic breeding ewes plus suckler cows on 560 upland acres in Gloucestershire

Targeted monitoring of ewes and lambs to reduce medicine use is improving flock health, lowering culling rates and resulting in faster finishing lambs for Pauhla and Martin.

As an organic flock, the couple were already focused on good health and disease prevention but worked closely with their vet to develop a flock health and management plan with an emphasis on a robust and resilient flock with minimal intervention.

"Making a positive spend on testing and diagnostics leads to savings elsewhere and is well worth the investment," says Pauhla. "Simple diagnostics can be done pen side helping you make proactive rather than reactive decisions."

Vaccination and parasite monitoring play a key role, while monitoring and maintaining body condition to ensure ewes provide good colostrum is critical for lamb management. The couple blood test pre-lambing to check ewe nutrition status. They also measure colostrum quality, which has reduced watery mouth, lamb mortality and mastitis.

"When you have a problem, get your vet involved," advises Pauhla. "We ask ours to blood test a small number of lambs, checking for passive transfer of immunity from colostrum. It's a worthwhile investment as it tells you if those lambs really did get enough good quality colostrum or if you have another underlying issue."

CASE STUDY: **Ernie Richards**

Managing 1,000 ewes on a 350-acre upland farm in Powys

Careful selection and breeding are key to producing quality, healthy pedigree Lleyn sheep, keeping costs low and maximising sales for first generation shepherd Ernie, who works for Stuart and Helen Morris on their upland farm of permanent grassland and new leys.

Flock health is also a priority, with Ernie adopting a more proactive approach to vaccination in recent years in both the breeding flock and prime lambs. "We feel prevention is a lot better than cure, therefore using a core vaccination policy is the best way to prevent contagious diseases and problems," says Ernie. "Trying to reduce our antibiotic usage is also a big part to become more sustainable and ensure resilience."

He strongly believes a healthier flock leads to more sustainable protein production and higher welfare standards, therefore reducing the carbon footprint. To encourage more farmers to adopt a similar practice, Ernie would like to see better understanding of responsible medicine use and government support to create a national flock fully vaccinated against contagious diseases.

Flock health planning is an essential on-farm method or improved animal health and welfare, leading to increased efficiency and therefore sustainability. Agricultural support is shifting away from direct payments for the amount of land individual farmers manage, towards environment and sustainability focused payments – and recent encouragements for regular communication with vets and advisers is a positive step towards a more sustainable sheep sector.

In England the introduction of the 2023 Animal Health & Welfare Pathway, as part of the Sustainable Farming Incentive, promotes higher welfare animals and underpins the high international reputation of UK produce. Similar schemes are being released across the devolved nations. For example, the Scottish Government is offering funds to farmers to investigate and build on priority health areas. Additional funding through equipment and technology grants boosts the sector's ability to invest in new technology and modern equipment to promote and improve higher welfare animals and underpin the high international reputation of UK produce.

England, Scotland and Wales now require veterinary attestations relating to farms selling livestock products for export, ensuring animals or their products being exported have undergone regular health visits, confirming they are free of notifiable diseases and their owner has awareness of these diseases. Supporting farmers to improve and increase their environmental work, while remaining prosperous and productive, is key to improving sustainability.

Proactive welfare management is crucial to ensure the reputation of the UK sheep sector is upheld, as well as having positive impacts on both responsible medicine use and reductions in each farm's carbon footprint. Not only does animal disease impact on the overall welfare of the animal, but there are also economic concerns associated with the disease, such as loss of performance, preventative measures and treatment costs, with the Animal Plant & Health Agency (APHA), estimating endemic diseases cost the sector around £85 million per year.

A report in 2020 highlighted farm animal health and welfare as the low hanging fruit to tackle climate change challenges suggesting improved animal health and welfare will increase both animal and the system efficiency, reduce culling and waste[124].

RESPONSIBLE MEDICINE USE

The long-term sustainability of the UK sheep sector relies on the efficacy of key animal medicines – notably antimicrobials (mainly antibiotics) and parasiticides. Animal health and welfare, animal productivity, and therefore carbon footprints, rely on them.

To slow down the development of resistance to these medicines, for the sake of animals, humans and the planet, it is vital they are used responsibly – as little as possible, as much as necessary.

Through the work of Responsible Use of Medicines in Agricultural (RUMA) Alliance, UK livestock sectors have significantly reduced antibiotic use by encouraging proactive flock health management and best practice. The biggest reduction for sheep has been the move away from oral antibiotics in young lambs. There may be situations where farmers understand the actions required and want to implement change, but resources are not always available or are unaffordable, as highlighted over 2022-2024 with issues surrounding vaccine availability and supply.

The Sustainable Control of Parasites in Sheep (SCOPS) Group is another example of where an industry-led group has generated and shared best practice advice on sustainable use of animal medicines – promoting the fine line between ensuring animal health, welfare and performance (the latter linked to lower carbon footprints) while cutting anthelmintic usage (to slow the speed of resistance developing, cut costs, save time and reduce the amount of chemicals passed in animal dung).

An example of an industry-led initiative to drive improvements in sheep welfare was the five-year UK Sheep Welfare Strategy, launched in November 2023 and encompassing focus areas to drive health and welfare. As part of this initiative, six strategic goals have been defined to lead to a more sustainable individual and national flock. Focus areas include healthy feet, appropriate body condition score, thriving lambs, collaborative flock management, positive welfare and sheep comfort.

One Health is a unified approach to balancing and optimising the health of people, animals and the environment. Responsible medicine use is advocated through the collaborative and coordinated work of industry-led groups such as the Responsible Use of Medicines in Agriculture (RUMA) alliance, Sheep Vet Society, and the Sustainable Control of Parasites in Sheep (SCOPS) group. The UK Sheep Welfare Strategy, led by the Ruminant Health & Welfare Group (RHWG) has six strategic goals (see graphic) and is another example of an industry-led initiative to drive improvements.

A specific example is the sector efforts to reduce antibiotic use co-ordinated by RUMA. Each UK livestock sector has worked on targets to provide usage data and prioritise actions to reduce usage where possible. This has led to the development of an E-Medicines Hub to collate farm data and a number of action plans developed by each sector.

For sheep this has seen a significant reduction in the use of oral antibiotics in young lambs, supported by hygiene at lambing, good ewe and lamb nutrition, and campaigns to increase preventive vaccine use for abortion infection, footrot and pasteurella.

Vaccines

Animal vaccines are well-used in the UK sheep industry to prevent and control disease, improving efficiency and driving sustainability, and supporting a One Health approach, However, vaccine progress has been hampered by serious inconsistencies in supply and the government needs to place higher importance on secure and reliable vaccine supply chains.

Preventing and protecting animals against diseases through vaccination will lead to improved health, reduced waste, increased productivity gains and lower carbon footprints, as well as more responsible use of medicines.

Sheep farmers have made huge strides in increasing vaccine use to improve animal health and encourage a sustainable sheep sector. There may be situations where farmers understand the action required and have the drive to do so, however resources may not be available or may come at a cost the business cannot afford.

An example of this has been seen since 2022 with the issues surrounding vaccine production and supply. Farmers are aware of the positive links between animal health, productivity and sustainability but production/supply of product continues to be a barrier. The lack of consistent vaccine supply also impacts on the sector's ambition to reduce the use of antibiotics wherever possible.

Sheep farmers have made progress towards government and industry ambition for preventative measures for specific health challenges within the livestock industry.[128] The total number of sheep vaccine doses sold increased by 12.6 % between 2012 and 2021. Approximately 36.7 million sheep vaccine doses were sold in 2021[128], indicating a huge uptake and improvement in the nation's flock.

The lack of vaccine availability experienced over recent years is putting many flocks at risk. During 2021, 63 % of the national flock was vaccinated against clostridial diseases and 51 % against pasteurellosis, which lasted well into 2022 and to some extent 2023[128]. Since then, due to supply issues, farmers have struggled to obtain these vaccines as well as those that target toxoplasmosis, enzootic abortion, footrot and orf, all of which often have catastrophic consequences for the individual animal. The orf vaccine went through a change in manufacturer with several suppliers out of stock until July 2023[128].

In terms of vaccine development, there are a few sheep-specific products currently under development, such as those targeting internal parasites, sheep scab and the louping ill virus. It is important these come to market to further improve the health of the national flock, but development, production and the authorisation process takes time. The vaccines under development would not only make a huge difference to sheep health and welfare but also reduce the need for dipping with organophosphates, reducing the environmental challenges associated with spent dip disposal.

Newly emerged diseases, linked to a warming climate, are bluetongue and Schmallenberg. Outbreaks in the UK in 2023 and 2024 promoted discussions around vaccine development for these too.

New vaccines are currently under development and the demand for existing vaccines is increasing, but there is no apparent increase in vaccine production capacity and limited government encouragement. Achieving a high level of quality and responsibly produced food self-sufficiency requires secure and reliable vaccine production and this should be accepted as being of national strategic importance.

Parasites

Gastrointestinal nematodes are still one of the biggest issues in the UK sheep flock. Gastrointestinal nematodes pose a notable effect on the health and welfare of sheep, with clinical signs such as reduced growth rate, reduced milk production and reduced body condition being observed and contributing major economic losses. Charlier et al. reporting helminth infections as costing the European ruminant livestock industry €1.8bn annually.

Resistance to anthelmintics is increasingly becoming a worldwide issue, with multiple resistance reported in the older broad-spectrum classes of anthelmintics (white - 1BZ, yellow - 2LV, clear - 3ML) and resistance developing towards monepantel (orange - 4AD). Without successful intervention, this loss of parasitic control will pose a serious risk to animal health and welfare, may result in loss of sheep production due to poor economic returns, and may significantly increase greenhouse gas emissions of sheep production, negatively affecting the UK's net zero targets.

The Sustainable Control of Sheep (SCOPS) industry-led group was firmly established by 2003 to combat this impending problem, as early anthelmintic resistance often remained unrecognised in flocks with sub-optimal performance reported. Findings by Learmount et al. estimated utilising management guidelines set out by SCOPS could provide a significant cost benefit of >£5,000 per annum on large farms.

Both Moredun (a livestock health and welfare research and education organisation) and SCOPS advocate a 'test don't guess' approach to reducing anthelmintic resistance and are leading the research behind the targeted selected treatment approach that aims to treat only those animals that need it, rather than blanket treating the whole flock. This approach reduces reliance on anthelmintics and potentially slows down resistance.

Moredun is leading on a five-year £6m collaborative project to further research a vaccine against nematodes, which may prove a valuable tool in combatting anthelmintic resistance. SCOPS supports alternatives to anthelmintics as a key area for reducing anthelmintic use, and a move to sustainable farming approaches will hopefully see benefits to controlling parasite burden in sheep, but more research will put the sector in a stronger position.

Lameness

Lameness is another key health and welfare focus area for the sector. Viewed as a complex condition to deal with, it poses a concern for animal welfare, with economic losses occurring from both the treatment costs and reduction in performance.

Lameness directly impacts animal welfare and presents a risk to industry reputation, hence the Farm Animal Welfare Committee setting targets to reduce flock prevalence from <5 % in 2016 to <2 % by 2021.

Winter et al. estimates footrot to be present in >90 % of flocks contributing to 70 % of overall flock lameness, whereas contagious ovine digital dermatitis (CODD) accounts for approximately 30 % of flock lameness and is present in 35-60 % of flocks. Scald in lambs can erupt quickly, particularly if environmental conditions are ideal and if footrot in the adult flock is not controlled. Vaccination is being used to reduce prevalence from 12.3 % to 2.5 % and, through long term commitment to the five-point plan (an industry-formed tool for farmers to adopt to control lameness in sheep) farmers can reduce on-farm lameness and achieve the Animal Welfare Committee lameness level, as has been demonstrated in a study by Clements and Stoye.

Iceberg diseases

Another area under investigation is the role of underlying diseases not always obvious through clinical signs – iceberg diseases. These often have a low level of clinically diagnosed animals, while many sheep are sub clinically affected, impacting health, performance, longevity and subsequent lamb viability and growth.

Increased farmer-vet engagement is allowing more sheep farmers to investigate their flocks for iceberg diseases, with record keeping and routine screening incorporated into flock health plans. Blood testing is used as the primary methods of clinical diagnosis, except for ovine pulmonary adenocarcinoma (OPA), where thoracic ultrasound scanning has emerged as the primary source of surveillance in live sheep. All respiratory and wasting diseases classified as iceberg diseases are contagious within the flock and strict culling policies, sourcing replacements from stock of known disease status, and quarantining procedures are strongly advised.

OPA (also known as Jaagsiekte) is a contagious lung neoplasm of sheep, which is characterised by chronic respiratory illness associated with a loss of weight, reporting a 6 % prevalence in dead ewes in England, later reporting that 24 % of cull ewes displaying signs of OPA were found to have lesions consistent with OPA upon post mortem. Transthoracic ultrasound is used to determine the presence of the disease, with scanning surveillance having increased in Scotland, which may be the result of increased awareness[126].

Border disease, a congenital viral disease, is characterised by increased barren rates, abortions, stillbirths and the birth of small weak lambs with Gonzalez et al. reporting decreased weight gain and increased days to slaughter in infected lambs. Initial diagnosis would be determined via blood testing for the presence of antibodies or the virus itself, followed by routinely testing replacement stock in flocks where the disease is endemic.

Caseous lymphadenitis (CLA) is caused by the organism Corynebacterium pseudotuberculosis and, although common is sheep flocks, often goes unnoticed due to a lack of clinical signs. Reproductive performance may be effected and chronic wasting occurs resulting in thin ewe syndrome, with prevalence of infection being lower in sheep under one year of age, with increased incidence occurring post shearing due to potential contact of uninfected sheep with excreting organisms from infected sheep.

Maedi visna (MV) is a significant disease transmitted via a lentivirus, predominantly via milk or colostrum, and is often clinically identified when the seroprevalence is approximately 60 %. Ritchie et al. estimated 100,000 ewes within the national flock could be affected with MV, almost a four-fold increase compared to 1995/96, resulting is substantial production losses such as a 10 % increase in lamb mortality, 20 % increase in forced culling rate and a reduction in cull ewe value due to chronic wasting. The Premium Sheep & Goat Health Scheme (PSGHS) which monitors MV has identified infection in <1 % of members flocks, but only approximately 9 % of UK flocks are accredited to the scheme, highlighting the importance of understanding clinical signs and ensuring good biosecurity between flocks.

Ovine Johne's disease (OJD) is caused by the bacterium mycobacterium avium and results in chronic enteric inflammation and a reduction in nutrient absorption, reducing performance and causing dramatic weight loss. Despite animals becoming infected during the first few months of life, typically via the faecal-oral route, clinical signs often do not manifest until adulthood. Data on the incidence of OJD in UK flocks is largely unknown, however a 2012 fallen stock survey estimated it to be 5.6 %[157]. As with MV, the PSGHS is available for Johne's screening, but uptake is low. A Johne's vaccine is available.

PSGHS also operates the government's Scrapie Monitoring Scheme which is of particular importance in exporting breeding animals and germplasm, including to Northern Ireland, which is considered scrapie-free.

There are a number of independent laboratories that offer tests for various iceberg diseases but do not run these tests as part of a recognised national health accreditation scheme.

There are many examples of where iceberg diseases directly impact flock health and therefore sustainability of the individual business and sector. Iceberg diseases usually lead to increased ewe mortality or premature culling, reducing flock productivity and profitability. Not only does disease reduce the productive lifespan of breeding ewes, it increases replacement rates (by as much as 23 % in cases of OJD), reduces the number of lambs available for sale and incurs additional rearing costs of retaining replacement ewes[163]. Resultant flock greenhouse gas emissions will be higher due to increased number of ewe lambs being retained for a longer time periods, as well as reductions in performance seen in finishing lambs. Research shows, for example, a 6 % lower daily liveweight gain in lambs from ewes with MV and 20 % reductions in lambs with border disease[164].

Breeding and genetics

There is high engagement levels amongst UK sheep farmers with farm-level genetic improvements through the use of on-farm records, use of Signet Breeding Services and Sheep Improvement Limited, and the development of identifying genetic markers via genotyping.

The move towards recording and estimated breeding values (EBVs) for a range of maternal traits such as longevity, immunity and resistance to parasitic gastroenteritis, and milk yield, help farmers to select for traits that support health and welfare improvements at the same time as productivity improvements.

The government's 2023 Precision breeding bill (Genetic technology Act) is another focus area for improving sustainability in the future through breeding and genetics. By altering the regulatory requirements governing genetically modified organisms, the use of precision breeding technologies, via the genetic technology bill, may pave the way to increase resistance to disease. However, further understanding is required surrounding the animal welfare implications.

Changing the regulatory requirements governing genetically modified organisms has opened the way for potential health and welfare improvements to be made via the insertion of resistance genes in the coming decades. This technology is being progressed in plants at these early stages in regulatory change and is expected to be used on livestock in due course – but this requires tight and effective controls to avoid any short or long-term negative consequences.

Research by Haskell et al. identified health and disease resistance as having the largest interest from industry partners, with 90.9 % of respondents planning to capture data over the next five years, with other traits including methane output and reproduction proving important areas of investment.

Other interventions

Castration and tail docking is another area under discussion for improving welfare and, arguably, comes within the objective of seeking true sustainability via minimum interventions. Both practices are permitted under legislation (the Protection of Animals (Anaesthetics) Act (1954), the Veterinary Surgeons Act (1966), the Welfare of Livestock Regulations (1982), the Animal Welfare Act (2006) and the Mutilations (Permitted Procedures) (England) Regulations (2007)) and are used widely across the sheep sector.

Research has shown standard castration methods cause pain, with lambs still experiencing pain four to five weeks after castration. But it can also be argued to not castrate or not reduce tail length also has serious detrimental welfare outcomes. Recent advances in welfare assessment and an increasing consumer interest in farm animal welfare has led to further examination of these practices, defined as 'mutilations' in the 2022 Farm Animal Welfare Committee report.

Depending on the system in which lambs are reared, castration may be deemed necessary to reduce the risk of ewe lamb pregnancies, facilitate management of store lamb finishing or reduce fighting within ram lamb groups. A trade-off is that keeping ram lambs entire encourages rapid growth and finishing can be achieved quicker. Testosterone, a naturally occurring growth hormone, drives lean meat yield, which is increasingly seen as important trait in lamb carcases. But if grass quality is low, ram lambs may not reach the desired market specification, due to lower fat levels typically observed in finished ram lamb carcases.

The Farm Animal Welfare Committee report encourages farmers to question the necessity of castration within their own businesses and whether alternative methods and management practices, such as different finishing systems, are achievable within their enterprise. The report also called for legislative change to allow two, recently developed pain-reducing devices to be brought into use – Clipfitter (a hybrid burdizzo and clamping tool) and Numnuts (a device that applies a local anaesthetic at the same time as a rubber ring).

Castration is regularly used to avoid taint in meat taste and a number of British supply chains will not take lambs that are entire but the perceptible taste difference in entire lambs compared to castrates or female lambs is being investigated. It is important that Defra stands by its commitment not to ban castration or tailing, but rather to incentivise methods shown to reduce pain.

Tail docking has been widely used in lowland systems to reduce the build-up of faecal matter, effectively reducing the risk of flystrike (subcutaneous myiasis), with 5 % mortality estimated in affected animals. UK regulations state tails must be long enough to cover the vulva of the female and the anus of the male, with research by Fisher et al. demonstrating that medium length tails resulted in lower faecal soling (dags).

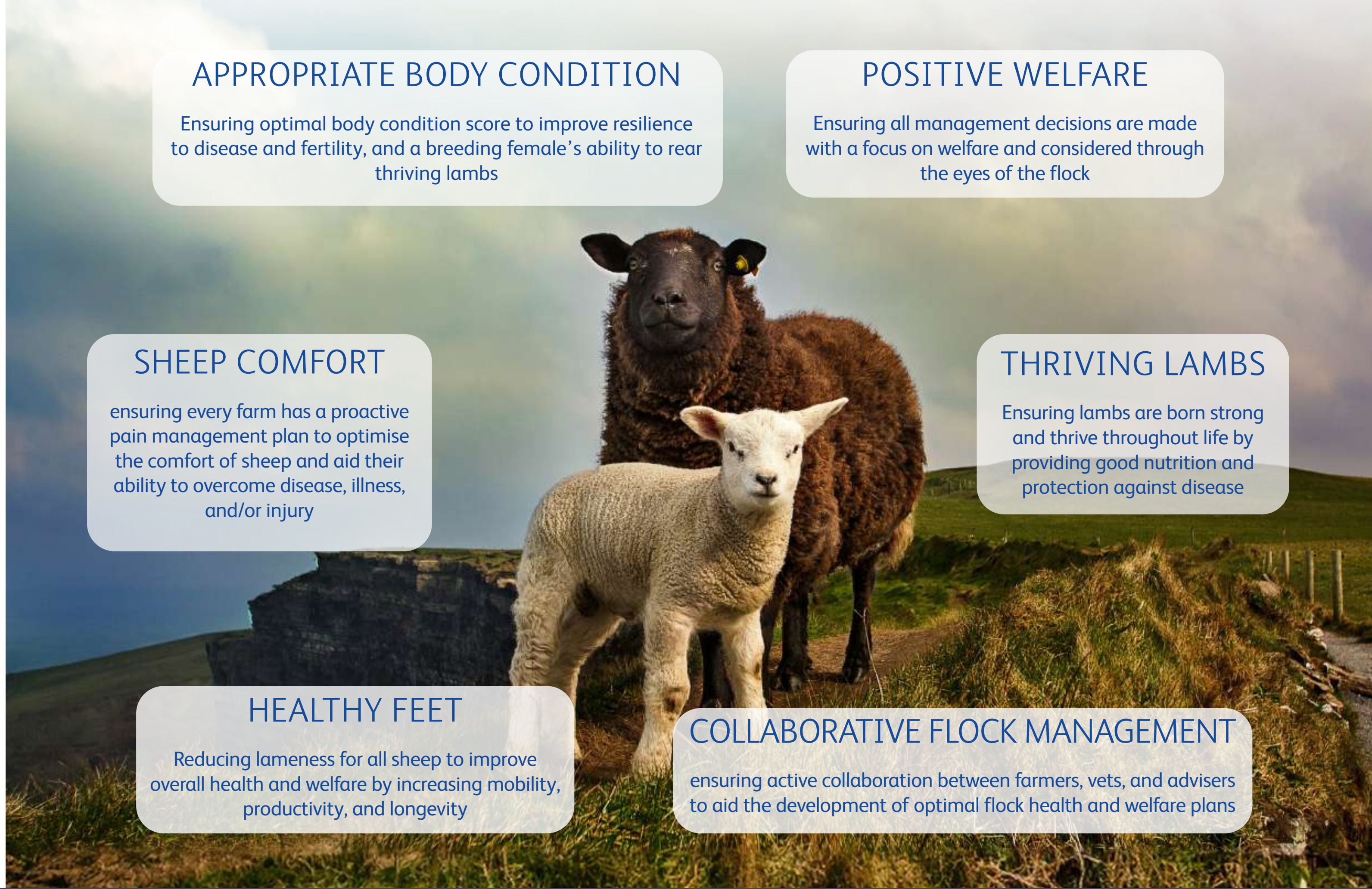
Although there may be significant negative welfare implications of not tail docking, the sheep sector is in an era when it must look at multiple rather than singular solutions. Farmers are now looking at genetics to provide answers in terms of breeding for shorter tail length, natural shedding of wool, management practices to reduce faecal soiling – such as minimising parasite burden through grazing management and by following SCOPS guidelines for effective use of anthelmintics – and looking at genetic selection of ewes with reduced faecal dag scores.

Reputation

As an industry, the UK sheep sector's national and global reputation has become increasingly important, particularly its reputation for the proactive way livestock is cared for and looked after. Seeking high levels of animal welfare with productive and profitable farming systems is a key element in an industry that starts with a good public image based on free range and extensive farming methods.

Overall, through the involvement with veterinary professionals, routine health screening and government incentives and payment schemes, the objective is that prevalence of disease in UK sheep flocks will reduce. This will impact on the direct performance of the animal, reducing the carbon footprint of sheep production and improving the health and welfare of the animals while also further enhancing the reputation of the UK sheep industry.

Figure 3. The six strategic goals of the Ruminant Health & Welfare Group's UK Sheep Welfare Strategy (2023-2028)



CHAPTER 3.6

Positive attributes: Rural economies, communities and infrastructure

For centuries the traditional stratified system of the UK sheep industry has played to the strengths and weaknesses of the varied terrain, landscapes, environments and productivity of UK agricultural land.

The UK hills have been an integral part of this stratified system, producing crossbred breeding replacements from hardy ewes for sale into the lowland sector, plus store and finished lambs as well as wool. The foundations of these stratified systems are based in severely disadvantaged, disadvantaged and less favoured areas (LFA) of agricultural land, which account for 45 % of UK agricultural land. Here grassland productivity is poorer, yet hardy native breeds have become adapted to the less favourable conditions, converting the grass into valuable breeding animals and ultimately a source of rich protein.

While not every sheep farmer in the UK is involved in the stratified system – currently 51 % of farms adopt this system, with most of the remaining adopting more of a closed flock replacement policy – UK sheep farming plays an important role in utilising land often unsuitable for other forms of food production and creating a host of public goods as a byproduct, including a range of social benefits that benefit the wider public and business community.

In many of the more remote rural areas, livestock farming can be the foundation and a key driver in terms of business activity and rural economy generation. Typically, these remote regions include UK's upland landscapes where sheep farming generates a specific interaction between people and place, which is important to the cultural heritage, stewardship and community, with farming providing the backbone and contributing to the social fabric of those areas.

CASE STUDY: **Will Rawling**

1,100 purebred Herdwicks plus composite ewes and suckler cows on 1,200 acres of unfenced Lakeland fell in Cumbria

Will Rawling's Lake District farm is as close to nature as possible with management practices developed to be sustainable as part of Higher Level Stewardship, including 30 acres of butterfly habitat.

He has seen reduced costs without compromising production, with his son managing the land to grow good grass without using chemicals. With a family history of fell farming stretching back 500 years, the family uses the traditional hefting system with the sheep on the fells. Will said the difficulties come from government (and Natural England) policies, which are well meaning but inappropriate for their area.

"Striking a balance between traditional practices that have underpinned all Lake District farms and delivering for nature while at the same time producing food as a commercial product is not always easy to fit into current schemes," he says.

Will believes there should be a dedicated free land manager adviser service for all the different areas of sustainable farming.

Sheep farms require services such as veterinary support, feed merchants and machinery mechanics, to name a few, providing jobs to people within these rural areas and providing future generations with traditional crafts and industries and trades to go into. This in turn creates a bedrock of local services and activities valuable for local inhabitants and visitors alike – pubs, schools, shops, churches and social/cultural events – all of which support the very community they are set in and drive economic activity.

Farmers often participate in other areas of employment and societal roles, such as parish councillors or organisers of shows/events, leading to the development of cultural and community traditions. There are usually strong ancestral links to the area, with farmers viewing themselves as custodians of the land and bringing about a wealth of culture, history and a sense of responsibility.

An example of the economic importance of sheep farming comes when looking in Wales. Sheep production forms the backbone of Welsh agriculture, with 75 % of breeding ewes being situated in the uplands, compared to 44 % on the uplands of England, and 80 % of the land is designated LFA. It is estimated Welsh family sheep farms contributes £8billion annually to the Welsh economy, with agriculture accounting for 30 % of registered businesses in the UK uplands, and accounting for 15 % across all rural areas. While there has been a gradual loss in agricultural employment in rural areas, there has been a growth in the service sector.

In the uplands, the Basic Payment Scheme (BPS) and a range or agri-environmental schemes have been the predominant income base. However, with altering payment schemes leading to reward for public good provision, there are opportunities for farmers to review their income streams while improving sheep production.

The most recent Farm Business Survey results showed 58 % of farms with LFA grazing make less than £25k per annum profit, so it is important to look for alternative income streams with the reduction in BPS.

Maintaining sheep in less favoured areas keeps skills alive and offers entry routes for new entrants, with ingoing capital expenditure relatively low after breeding stock purchases. Additional support, such as interest-free loans for new start-ups, mentoring schemes, improved broadband services and facilitation group to encourage collaboration and avoid isolation would also help.

Sheep farming keeps people living and working in these areas, creating need for additional jobs. A recent example of this is the announcement of the government's Small Abattoir Fund, launched at the end of 2023, to maintain local abattoirs, increase rural employment, support the development of local artisan food production, reduce food miles and raise animal welfare - all of which are pillars of sustainability.

Sheep farming in rural landscapes also adds to public services, infrastructure and local economies through social activity and the role of farmers in land management. Land management by farmers increases access for the public via the creation of roads, paths and open access areas (land under the Countryside Right of Way Act) – landscapes ideal for recreation, with access to the natural environment increasing overall wellbeing.

Sheep grazing not only manages a unique ecology and biodiversity within the landscape, but it increases available pasture and reduces the opportunity for the land to become overgrown by invasive vegetation such as bracken, molinia and coarse vegetation that would otherwise restrict public access, as seen in a case study on a Welsh sheep farm .

The UK is home to more than 60 native breeds of sheep, which over centuries have been purposely adapted to the harsh conditions of some of these areas to best utilise native forage – therefore underpinning the stratified sheep system. These breeds all have their own characteristics and suitability for our varied landscapes, often originating from a very specific part of the country. These sheep and the people who look after them have shaped the landscapes we are familiar with and created the communities that keep rural areas alive.

There are specific sheep breeds that contribute to culture, heritage and tourism, harnessing local and adapted sheep breeds in landscape promotion and management as well as potentially supporting a strong food culture and food tourism. Utilising the British Heritage Sheep scheme, more could be done to sell the story of local sheep meat (and other products) focusing on the animals age, breed and the landscape in which it was reared.

Utilising local or iconic breeds can open avenues for direct selling or niche markets, allowing lambs which may fall out of the standard carcase classification specification to be sold at a premium. This may lead to a cooperative approach in marketing with sheep meat from breeds that struggle to meet standard retail market specifications, yet are synonymous with an area, allowing the market to support a traditional approach that many remote areas are founded on.

CASE STUDY: **Neil Cole and daughter Ida**

2,000 ewes plus suckler cows and Dartmoor ponies on 2,000 acres of Dartmoor hill in Devon

Neil is keen to promote the important role farmers play in sustainability and environmental preservation, based on the experience of farming with his brother and now also his daughter over three sites in the Dartmoor National Park.

They took a business decision to farm less intensively, due to the restricted productivity of the high ground on the family farm, and are now involved in specific bird-related projects, as well as other systems to preserve the landscape via environmental schemes.

"When we began with the wader bird project it made us think we need to promote the good we do for wildlife, while producing the food the consumer wants and being realistic about the problems," Neil says, adding that they also offered their farm for a curlew project supported by King Charles.

"Our major challenge is the public. They don't realise their effect on ground nesting birds with their presence, waste and dogs in nesting areas," he says.

"We are producing quality breeding ewes to transfer through the stratified sheep system to the lower land, while also producing high quality food and delivering for the environment. HRH King Charles always appears extremely passionate about supporting British farmers and the nature gains they are delivering."

Not only does this approach support farming financially, but it also brings people together to tackle problems communities may be facing. In some cases, marketing initiatives support sustainable rural communities and contribute a percentage of the company profits to supporting upland fell farming. These additional benefits need to be included in sustainability assessments, demonstrating the need for holistic metrics and assessments.

Of the 14 UK national parks, 11 overlap with less favoured area land. As just one example, it is reported that four million people visit Eryri National Park (Snowdonia) annually, with the annual visitor spend in the Lake District National Park being £1.1bn per annum. But tourism can bring challenges to farming communities and fragile landscapes, causing problems such as blocked gateways, increased traffic congestion, litter, risk of fires, and sheep worrying by dogs. These problems are regularly reported within national parks that act as honeypots for visitors and this can also lead to the increased cost of local goods, including housing, and additional planning restrictions on building, development, and even sustainable energy projects.

In 2019 it was estimated that 772,000 households in the UK reported having second homes with second homes being used primarily as holiday lets or as accommodation while homeowners are working away from their main residence. Holiday lets bring income from tourism, with an average annual turnover estimated at £24,000 and create the need for additional services, but can significantly increase house prices outside the budgets of local residents pushing them out of their homes and creating ghost towns in the winter months.

The value of national parks is questionable, not in terms of that they are aiming to achieve but because they create honeypots and damaging differences across border lines that can disadvantage farmers in and outside these areas.

Vaznonienė describes wellbeing as 'one of the most important issues facing the world today and is central to the development of social policy for rural areas', with wellbeing being characterised by personal, community and societal wellbeing. Social isolation is one of the challenges facing rural communities, with mental health being one of the largest issues facing agriculture.

Issues such as access to affordable housing and public services cause negative wellbeing and four out of five young farmers (under 40) believing mental health is the biggest problem facing the industry today. Livestock auction marts are one of the remaining spaces where livestock farmers can guarantee consistent social interaction and to experience community, both determinants proven to improve physical and mental health, as well as offer a range of business activities.

CASE STUDY: **Bob Kennard**

Creator of the British Heritage Sheep movement, based on his experience promoting home-produced organic meat

Bob says his neighbours thought he was completely mad and wouldn't last when he moved to a small farm in mid Wales in the late 1980s and set about establishing a brand that sold 'meat that tasted like meat'.

But he and a small group of organic farmers started selling lamb, beef, pork and chicken with an emphasis on breeds, geographical location, the name of the farmer and the story behind them. Graig Farm Organics was born as a premium product offering eating quality, flavour and texture.

Bob says: "At the time, very few people doing what we were doing and we had to try and get over a complex message in a simplistic way. We were carving out a niche that didn't exist so it was difficult to find customers. We started with a farm shop and went into mail order in the mid 1990s, which was unusual at the time. It was hard work for a small organisation.

"It's become easier, as the current generation of consumers is actively looking for traceability and food with the story behind it. The challenge now is finding local abattoirs and coping with onerous regulations and hoops to jump through. This has made things more expensive than when we set up."

In more recent years, Bob has been instrumental in encouraging interest in mutton and lobbying for small, local abattoirs. He is also the instigator of British Heritage Sheep, promoting the ABC of sheep meat – age, breed and the countryside (location) it's reared in.

He says: "There is so much potential and so many directions we can take British Heritage Sheep and our current efforts are looking at ways to identify and provide traceability to consumers on the age and breed of the animal they are eating, and where it was reared."

CHAPTER 3.7

Positive attributes: High quality protein and fibre

Sustainable sheep farming practices that rely on well-managed grasslands ensure high-quality wool and meat products for domestic consumption and international export.

The sheep industry faces market challenges, including price fluctuations, competition from imports and changing consumer preferences. Diversification of products, such as promoting the use of wool and sheep meat in various culinary traditions, can create new opportunities for farmers.

Approximately two-thirds of the total utilised agricultural area in the UK is grassland[26,27], with a large proportion of this comprising less favoured area (LFA) not suitable for growing human-edible crops. Barriers to growing human-edible crops in LFA include climate (temperature and precipitation), topography, soil characteristics (for example workability and trafficability), environmental designation such as Site of Special Scientific Interest and peatland, and access (for example, not being able to get arable machinery down narrow country lanes).

Conversion of grassland areas that could potentially be used to grown human-edible crops would only result in marginal overall increases in total cereal/grain production. A recent study from South West England investigating the feasibility and impacts of converting grassland to arable under future climate scenarios found a low probability of sowing success for winter wheat, with some climate scenarios leading to yields of below three tonnes per hectare (while yields could be greater than 14 tonnes per hectare in the increasingly unlikely absence of climate change). Conversion to arable (often to feed non ruminant livestock) also resulted in higher CO_2eq emissions from the land and a decline in soil organic carbon under current and future climate scenarios.

CASE STUDY: **Susie Parish**

Producing top quality wool from a 500-head Gotland flock in Hampshire

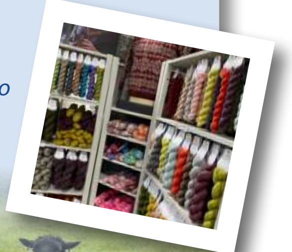
Creating world class knitting yarns from a low input system while investing in the landscape, biodiversity and welfare is being achieved by flock manager Susie Parish on Neil and Emma Boyles' farm in Hampshire.

"When we started on this journey we received criticism from people saying it was just a hobby, but we have shown there is potential to make money and in some cases more money from wool than from producing commercial lambs," explains Susie.

"There is a mindset among many farmers that wool is just a byproduct but this must be changed. It's the ultimate sustainable fibre and great for capturing carbon, " she adds.

The 500 Gotland sheep are all farmed with wool and skins as the main focus with meat being a byproduct. All processing (apart from scouring of the wool) takes place on-farm including spinning. The yarn is sold globally. Only a portion of the flock lambs each year, just enough to breed their own replacements, and Susie allows lambs to wean naturally.

"Because our focus is wool, the flock is not under any pressure and I don't need lambs to grow fast," she adds.



Livestock systems are often criticised for using crops or arable land that could instead be used for human food, with the supposition that feeding livestock to produce milk or meat is less efficient than producing crops humans can eat. Although this argument is valid for pig and poultry systems, in which most of the feed ingredients are edible by humans (grains, protein crops, etc), it does not account for a major advantage of ruminant systems – turning forage crops, byproducts and cellulose-rich feeds humans cannot or will not eat, into high quality protein.

Wilkinson and Lee showed the total quantity of land required to produce a tonne of protein was considerably higher for upland (27.6 ha) and lowland (22.5 ha) lamb compared to pigs (3.8 ha) or poultry (3.1 ha)[86]. But, when the proportion of pasture land within the total was accounted for, lamb production required considerably less arable land (1.1-1.6 ha) per tonne of protein produced compared to pigs and poultry (3.1-3.8 ha).

Lean red meats such as lamb and mutton are an excellent source of high biological value protein, B vitamins (including vitamin B12, niacin, pyridoxine, riboflavin, pantothenic acid and pyridoxine), minerals (including iron, zinc, selenium and phosphorus) and omega-3 polyunsaturated fatty acids (PUFAs). Per 100g serving, lamb can provide around 40 % of the daily recommended intake for protein, 12 % long-chain omega-3 PUFA, 65 % vitamin B12, 17 % vitamin B2, 12 % iron and 25 % zinc.

Despite these nutritional benefits of sheep meat, consumption per capita remains very low compared beef and pork, and very low compared to poultry. Reasons for the decline in lamb consumption in the UK include affordability (seen as a high-cost protein), convenience and preparation (fewer convenience options for lamb), dietary and food consumption trends (eating smaller portions, wanting to limit food waste and rise of popularity of plant-based diets), concerns over quality and consistency, and concerns over environmental impacts. But diversity in sheep meat should be embraced (as described in chapter 3.6) alongside the multifunctionality of sheep products available.

Wool is a naturally renewable and sustainably produced product but is currently undervalued and it's use underdeveloped. Wool value has decreased over several decades due to substitution by synthetic fibres and a lack of innovation and effective marketing. In 2021, synthetic fibres accounted for around 64 % of the global textile fibre output (with polyester alone accounting for 54 %), while animal fibres (the main animal fibre being wool) represented a mere 2 % .

Most farmers now consider wool an inconvenience given that it contributes very little to farm profit. Shearing is commonly more for animal welfare than income. Flocks of naturally wool-shedding sheep are increasingly common, and there is a risk more farmers will shift to wool-shedding sheep to remove shearing costs, threatening long-term supply of wool and adding to infrastructure costs.

In the quest for improving sustainability and reducing human impact on the planet, there is renewed interest in promoting the use of natural fibres in place of synthetic fibres in both traditional and innovative applications. Wool is a sustainable, climate-smart product, being renewable, hard wearing, fire resistant, biodegradable and versatile. Many types of synthetic fibre are derived from limited petroleum resources, giving rise to issues with resource depletion and large amounts of waste generation due to their non-biodegradable nature.

This is not to say that natural fibres are completely void of environmental impact, but their impacts tend to be less harmful compared to synthetic fibres. In addition, around half the organic matter of the fleece is carbon in flocks managed in extensive, natural systems. Wool grows naturally on sheep and is a stable form of sequestered carbon.

In terms of the environmental impacts of wool production, energy and water use must be considered, as well as chemical use (insecticides and pesticides used on sheep and chemicals used in the cleaning and processing of wool post-shearing), greenhouse gas emissions, waste generation and land use[201,202]. Nonetheless, given wools' unique qualities, along with the growing recognition of damaging impacts from synthetic fibres, there is growing opportunity for wool to play a key role in sustainability improvement, protection of a natural resources and circular economies.

In addition to increasing the use of wool in the apparel and textiles industries, there is a growing interest and need to find other uses and applications for wool. Some new and innovative applications for wool include packaging, building materials, thermal and acoustic insulation, compost, lanolin use in cosmetics, water management (filtration and flood defences), oil spills, peatland restoration and as a growing substrate. The true cost of synthetic fabrics is not accounted for in its relatively cheap market value and the use of wool in clothing and carpets and insulation is significantly disadvantaged by this.

CHAPTER 4

Measuring sustainability

Although UK agriculture contributes relatively little to total global greenhouse gas emissions, it still contributes significantly to the UK total – and with the net zero target now legislated in the UK, doing nothing is not an option.

The aim of net zero is to reduce emissions to as close to zero as possible, with the small amount of remaining emissions absorbed through natural carbon sinks. This is particularly relevant in grazed ruminant livestock systems where enteric methane emissions are part of a carbon cycle that includes the absorption (sequestration) of carbon back into soils and vegetation.

Greenhouse gases all contribute to global warming, but they differ in how long they remain in the atmosphere and how powerful the warming effect is. Using a standard carbon dioxide equivalent (CO_2e) measure makes comparison between emissions easier. Global Warming Potential (GWP) is used to standardise all greenhouse gases describing how much impact a gas will have on atmospheric warming over a period of time compared to carbon dioxide. GWP* and GWP_{100} are the two ways to represent global warming potential – see panel.

The complexity of environmental impact accounting typically leads to an over-simplistic use of an impact metric, for example carbon dioxide equivalent/kg product or unit of protein/energy, which does not represent the true impact and value of livestock products[7], especially when it comes to sheep systems.

It is flawed on both sides of the equation, as carbon dioxide equivalent (calculated using GWP_{100}) does not adequately reflect the different nature of methane, the main greenhouse gas emitted from ruminant livestock systems, compared to carbon dioxide (CO_2) and nitrous oxide (N_2O) in the atmosphere. Methane decomposes in the atmosphere, predominately through the action with hydroxyl (OH-) radicals, which form naturally through the reaction of water vapour and ultraviolet light, in essence 'cleaning' the atmosphere. Whereas carbon dioxide is highly inert and has to be directly removed from the atmosphere either through photosynthesis or dissolution. This means the lifetime of these gases in the atmosphere are very different from 10's of years for methane to thousands of years for carbon dioxide Unlike carbon dioxide and nitrous oxide, methane only remains in the atmosphere for around 15 years, meaning concentrations do not build.

GWP* VS GWP100

GWP* aims to model the impact of methane better and compare the warming effect it has relative to carbon dioxide over time, known as carbon dioxide warming equivalents. Under GWP*, methane emissions initially have a more potent impact than under GWP100, but due to its shorter atmospheric life and that it does not accumulate in the same way as carbon dioxide or nitrous oxide, it drops to having a significantly lesser impact, well below that from GWP100. Discrepancy between these two measures has created concern and confusion when trying to understand farm carbon audits.

Methane output

The majority of methane output from sheep comes from a natural process within the rumen that is the result of digestion of grass and herbage grown with few fossil fuel-based inputs. During digestion microbes in the rumen ferment feed consumed by the animal, producing methane as a byproduct, which is burped or belched.

Methane emissions can also come from manure storage, so funding of small scale anaerobic digestion plants on farm would aid reduction in methane loss and make it a resource rather than a waste.

Methane produced by the animal depends on the level of feed intake, the feed quality and intrinsic differences in efficiency of feed conversion. By increasing efficiency of production through genetic improvement and/or management improvements methane emissions per kg of output should reduce. But care needs to be applied in chasing methane reductions alone, as this could have wider environmental and market implications.

Kg of product does not adequately consider the value of livestock. For example, nutritionally, they are generators of valuable co-products, while also being recyclers of byproducts, up-cyclers of non-productive land, potential soil and biodiversity enhancers, and also offer social resilience platforms. And that is without considering the nutritional value of the product, given how nutritionally dense lamb and mutton is (as described in chapter 3.7).

However, there are alternatives to CO_2e/kg product which, even if not perfect, better reflect the impact and value proposition of animal-based products. They can, for instance, consider the natural turnover of methane compared to carbon dioxide and nitrous oxide via GWP*, which converts methane emissions into CO_2-warming equivalents ($CO_{2\text{-we}}$; ·). This metric is argued to more aptly represent how methane emissions translate into temperature outcomes at various points in time by considering its breakdown in the atmosphere (see panel). In this sense and when using GWP*, Costa et al. and Liu et al. reported reducing global livestock methane emissions by 7 % from 2020 to 2040 (at 0.35 % annual reduction in emissions) would stop further agricultural methane-related increases in global temperatures – analogous to the impact of net-zero carbon dioxide emissions (as explained by Allen et al.[213]).

Furthermore, reducing emissions by 5 % annually over this same time frame would neutralise warming that had occurred since 1980. However, if methane emissions were to rise by 1.5 % annually, the modelling with the GWP* method resulted in a 40 % greater climate impact than if methane emissions had been converted to $CO_{2\text{-eq}}$ using GWP_{100}. The use of these two metrics is currently scientifically and politically in debate, but has huge consequences for the sheep and livestock sector to realise net zero.

Both metrics report different things with GWP_{100} accounting for carbon accumulation and GWP* accounting for its warming impact, as such its highly beneficial for both metrics to be reported together to provide a clearer picture of the carbon and warming contribution of sheep production[212].

To replace kg product as the value proposition, beef-focused research by Lee et al. proposed $CO_{2\text{-eq}}$ per unit of recommended daily intake (RDI) of key nutrients provided. If we were to apply the same approach for lamb, using the carbon footprint figures of 37.4kg $CO_{2\text{-eq}}$/kg lamb meat, this would relate to 0.14kg $CO_{2\text{-eq}}$/1 % RDI. Considering GWP* and declining sector methane emissions the footprint for lamb could reflect a figure of 0.05kg $CO_{2\text{-we}}$/1 % RDI[217,212].

in addition the carbon removal capacity of the farm through soil and plant and vegetation growth and the potential for green energy production, reducing fossil fuel emissions, should also be considered, which could then realise net zero or even negative carbon emissions within sheep systems – which means gross annual greenhouse gas emissions less gross annual carbon sequestration, adjusted for renewables and waste management.

A critical further consideration to run alongside net zero targets is of course food production and sustainable land use, including the food producing potential of different land types and, subsequently, human edible food versus livestock feed consumed competition. What is often confused is the true and accurate land use potential of livestock to produce food, with total land area used as a metric instead of considering what food could be produced on that land. Consider, for example, the difference between a hectare of the uplands of Snowdonia (Eryri National Park) versus the Fens of East Anglia.

If sheep are raised on land not suitable for growing crops or as a user of waste-streams from the food industry as part of a multifunctional system and circular economy, the output of human edible food is considerably greater than the input of human edible food used as livestock feed. As such if you use a sustainability metric of food produced per unit of arable land, you will show lamb is the most sustainable protein.

However, even if not satisfactory from a pragmatic perspective, the reality is that a single metric will never do justice to the complexity and multifunctionality of the various sheep production system impacts and values. While some degree of simplification is inevitable, a multifactorial assessment approach will usually be necessary. Ideally, metrics should also account for the wider value of sheep in our food system, providing opportunities for biodiversity (through appropriate stewardship), restoring soil health, reducing the risk of wildfires, and supporting rural communities at a time of climate uncertainty[219].

Food system stakeholders and the media often appear to focus on ruminant livestock as the cause of climate change, inevitably concluding the most impactful mechanism for reducing greenhouse gas emissions is to reduce meat consumption and livestock numbers. This myopic view fails to account for the wider benefits of sheep systems for soil health, biodiversity, food security and rural social cohesion, or the role of grazing livestock in sequestering carbon into soil, therefore becoming an important component of mitigating climate change.

A recent meta-analysis published by Ivanova et al. demonstrated that adopting a vegan diet was only ranked seventh out of the ten most impactful changes consumers could make to cut their individual carbon footprints (see bar chart), with fossil fuel-related activities (car travel, long-haul flights and building energy efficiency) all having a considerably greater impact.

Although the benefits of sheep production are unequivocal, there still remains an urgent need to measure, benchmark and improve greenhouse gas emissions from every operation in the UK. As discussed in chapter 3.1, relatively little data relating to the greenhouse gas emissions from UK sheep exists, so figures quoted in the media or by activist groups are often outdated or not representative of UK systems.

It is essential to have a baseline to compare future gains against and to demonstrate and communicate sheep producers' dedication to improving sustainability. It is also vital for the sheep sector to continue to highlight and question outdated, bias and/or inaccurate information portrayed by the media.

Carbon auditing tools

Across the UK the number of farm businesses using carbon audits and auditing tools is growing rapidly as governments, retailer, commercial farm businesses and other farming industry stakeholders want to measure and mitigate agricultural emissions. In many cases they have become a useful management tool allowing the identification and monitoring of key performance indicators, benchmarks, profitability and performance.

However, it is clear the uptake of carbon calculators is significantly lower in smaller private businesses. The main reason for this is the lack of baseline and variation in calculation tools, their processes and outputs, but also the lack of certainty and incentives from government on the future direction of farming policy in the UK.

A number of commercial carbon footprinting tools exist (see table), developed independently with no set standard regarding the quality of information going in, the formulas used or the way information is reported – and consequently the same farm will come up with different results dependant on which tool is used. This can be valuable for a farm's self-assessment and improvement providing the same tool is used, but doesn't help in gathering information to use on a wider supply chain or even national basis.

There is a real need for harmonisation of key metrics across different tools. Maintaining a number of independent tools will encourage innovation but a standard methodology and the development of accepted indicators of resources and sustainability are needed long-term to allow aggregation and reporting of supply chain emissions (termed scope 3 emissions). They are useful to evaluate both the farm or enterprise current carbon footprint and the effects of making management changes.

Because tools vary so considerably, some are more detailed on the crop or livestock side, others require a greater level of data entry, and some use a number of assumptions to reduce the amount of information required to generate the carbon footprint. It's tempting to assume more data will increase the accuracy of the result – simply entering the number of head of sheep present on the farm gives a crude estimate of the carbon footprint, yet a more exact figure may be achieved if liveweights, growth rates, mortality, lambing percentage, feed types, forage characteristics, days at pasture etc, are taken into account. Nevertheless, the tools must be simple enough that they can be used on every farm and give consistent results, with recommendations as to how to improve.

Providing recommendations that are applicable to each individual farm is difficult at present, as although we know that meeting or exceeding key performance indicators should reduce emissions, some gaps within the science still exist, particularly relating to animal health. Accurate assessments of carbon sequestration into soil and held by vegetation are essential in any carbon footprinting tool used on sheep farms, as is the use of the GWP* metric, but, again, the capacity to include these varies considerably between tools.

Ideally, a standard carbon footprinting tool should be applied across all UK agriculture. At present, if two farms have different footprints, or the same farm uses two different tools in different years, there's no way to ascertain whether this is a true result, or is due to variation in tools, different levels of data entry (counting every last piece of baler twine or putting in the bare minimum), or simply the fact that, this year, one of the farms faced some serious weather, infrastructure or animal health challenges that changed crop, pasture or animal performance[222].

With many processors and retailers needing to quantify the scope 3 emissions of their supply chains, undertaking carbon assessments is going to be an increasingly essential part of market requirements in the future. Therefore, a level playing field will be required to ensure fair comparisons. The same problem applies when trying to compare results from different carbon footprint studies. It's vital there is improved consistency and confidence in calculator tools by having a standardised baseline and a platform that is user friendly and straightforward.

An example of confusion in recording is demonstrated in the recent Defra report on harmonising carbon calculators, where they found there are more than 80 carbon calculators with different levels of complexity and assumptions, which could lead to a different outcome from different tools used on the same farm. How can farmers be expected to trust and want to use tools like this when there is such discrepancy in the results?

It can be argued that if the same tool is used consistently it will lead to increased uptake and more on-farm improvements, as well as making comparison between farm types, regions and national data easier to utilise for policy direction. Some carbon footprint tools now offer scenario-based models to try to predict what impact a specific change on farm will have on overall carbon footprint, allowing individual on-farm benefits to be assessed. There still needs to be a monitoring process, enabling farmers to understand the impact of change on overall farm sustainability and assist in future decision making.

It might be tempting for individual farms to wait to assess greenhouse gas emissions until a standardised tool has been developed or chosen, yet this risks losing information both on environmental gains made over time, and changes in efficiency that may have a dual benefit in terms of improving both greenhouse gas emissions and economic cost.

It's therefore important for producers to pick a tool that fits the level of data entry and time available. Even if there may be a requirement to change tools in the future according to processor, retailer or governmental requirements, this does not outweigh the benefits of establishing a baseline now.

There are opportunities to cover the costs of carbon footprinting – through supply chain relationships, benchmarking groups, government schemes and pilot levy schemes – but they are not universally available yet. Government funding of on-farm carbon footprinting will be key to encourage uptake and integrate the practice into standard farm management. It may also assist with more consistent and reliable information for regional and national trends to be collated, allowing evidence-based policy decisions.

There is also a critical need for on-farm training and support for using these tools. In many instances farming businesses are one or few individuals who are expected to be experts in business, finance, plant health, animal health, environment, soil and nutrition

CASE STUDY: Ed Brant

500 ewes and 150 ewe lambs on a 1,480-acre lowland beef and sheep farm in Lincolnshire

Ed is committed to improving his flock by employing a detailed scanning and data collection system to optimise breeding and output levels.

He says: "We use performance recording to select and breed our own rams. We also record data when handling and treating animals and base treatments on weight and performance, using this to aid future breeding decisions."

The level of information being gathered on farm has grown from pedigree information and two weights per lamb, to scanning for muscle depth, CT scanning for potential terminal rams, measurements for parasite resistance and weighing lambs every time they are treated.

Ed continues: "We started with a small pedigree flock where all the information was recorded. As the flock grew, we have seen the benefit of improving genetics and tracking performance."

The farm has seen improved growth rates in lambs and better milking, prolificacy and mothering ability in ewes. It has also become easier to identify poorly performing ewes.

Challenges include the time taken for data collection and single sire mating, meaning more work at tupping. For any farmers thinking of doing more with data, Ed suggests: "Start collecting a bit of sample information, using it to gain the most value, before asking what do I need to know next to make better decisions in the future."

– so funding towards individual carbon audits is recommended. Farmers cannot be overly burdened and the sector needs support, smart solutions and increased trust in the tools and indicators drive progress.

Continuing to assess greenhouse gas emissions on an annual or bi-annual basis is essential, as footprints may vary considerably year-on-year and examining trends over time gives a more representative picture of a farm or enterprise's emissions than a single footprint.

Examining and understanding the results produced by carbon footprinting tools is essential. Given the close relationship between farm or enterprise efficiency and greenhouse gas emissions, many practices that improve economic viability will also reduce greenhouse gas emissions, yet deciding which aspects of production to improve maybe less clear-cut. For example, store lamb producers tend to have lower greenhouse gas emissions per kg of deadweight lamb than ewe flocks because they do not carry the environmental burden of the breeding flock. However, the economic margins associated with buying stores may not suit all systems – and store lamb systems can obviously not exist without breeding ewe operations.

Another example, where genetic selection has improved hill sheep profitability over time, primarily as a consequence of increased lamb weaning weight, greenhouse gas emissions per ewe and per kg liveweight may have increased because of a concurrent increase in ewe mature bodyweight. In some operations, lamb growth rates may be enhanced by creep feeding or providing supplemental feed as pasture, providing the economic and environmental impacts of increased concentrate use are outweighed by improved performance.

This takes us into the area of systems-based footprints, and ultimately even store stock coming onto a farm for finishing would carry a carbon footprint with them. A key ask is for research and development to allow systems based/linked farms to be assessed and consider the possibility of a simple system of carrying forward a footprint where animals are moving between farms.

CASE STUDY: **Richard Oglesby**

1,600 ewes plus suckler cows and red deer hinds within a 1,450-acre upland contract farming business in Northumberland

Grassland management and genetics are the two biggest drivers of success for Richard.

He says: "Our view is that sustainability and profitability go hand in hand on-farm, especially with the new environmental schemes. We have received increased income from the new schemes while also providing more biodiversity. Rotational grazing benefits the farm by increased stocking rates, reduced fertiliser and bought in feed, and increased carbon sequestration."

The focus is on rotating sheep and cattle at the right time and saving paddocks for winter grazing. Richard says genetics play a huge part and the system would not work without the correct livestock breeds.

"Ewes need to lamb outside unassisted and put on good body condition over the summer and maintain it. Lambs need to be able to achieve adequate weight gain from grass and ewe lambs need to achieve 40kg by late November so they can be tupped," explains Richard.

He believes the government could do more to incentivise improved genetics and performance recording on farms, enabling uptake of DNA testing lambs to overcome the challenge of single sire mating.

Yet in other operations, lamb performance might be better improved by enhanced pasture management and appropriate parasite control, with consequent positive impacts on soil health and biodiversity. The key message is there are a range of different sheep farming systems in play, and usually for a very good reason, but through footprinting and subsequent changes, individual carbon footprints can be minimised, often with associated productivity or environmental gains.

Further trade-offs may occur between carbon footprints and biodiversity, soil health, water use and other metrics. Therefore we must aim to minimise overall trade-offs across the operation and make evidence-based decisions based on clear sustainability goals. To put it simply – producers must ascertain where they are (baseline), where they'd like to be (reduced greenhouse gas emissions) and the best method of getting there, using accurate data.

Accurate record keeping is a vital tool for successful farm improvement, with baselining and benchmarking providing a reference point for farms to work from, evaluating farm performance and building upon specific sustainability parameters. Because of the large variation in performance relative to area, farm type, land use and soil type, there is limited data on how this affects sustainability. Therefore, consideration should be given to those operating under differing production contracts, extensive and intensive systems.

Add to this the multitude of sustainability assessments and metrics to choose from, and the risk is that confusion and misunderstanding is created around which metrics and benchmarking platforms should be used. This again highlights the need for a robust scientific baseline that looks at agriculture as part of a wider ecosystem, including on-farm actions these businesses are adopting, such as hedgerow planting and renewable energies (solar, wind and hydro power).

Any record keeping must be founded on the basis that metrics are consistent and science based across industries. It is also vital research is done across farming sectors to ensure metrics are appropriate across the board and include upland, lowland and mixed farming scenarios. To improve record keeping, farmers and land managers need to understand the basics of the metrics being recorded. Ideally, data collection and analysis needs to be simple, streamlined and harmonised to encourage adoption and the use of data at a farm and aggregated level.

But there must be consideration given to whether a global baseline should be set, especially considering the increased appetite of the UK Government to establish trading relations across the world. It will be absolutely vital for UK farmers to be competing on a level playing field with equal standards across the board.

It is disappointing the short life of methane compared to other key greenhouse gases is still not accepted through the use of GWP* rather than GWP100, as the inability to use what are considered more accurate metrics undermines the confidence in carbon footprinting.

Moving forward it will be vital to identify clear parameters for these tools to work within and a science-based approach to measurements. Although it would be preferable for development or investment in a universal tool for future policy progressions, it is vital there remains the option to use simplified versions that provide an overview into emissions, sequestration and farm performance and the things businesses can do to improve on these areas without having to have years' worth of detailed datasets.

More accurate and meaningful carbon footprinting method are key and must also always consider wider sustainability metrics. Of particular importance for the sheep sector is a better understanding of the multifunctional role of grass, the inclusion of whole food chains in footprinting tools, and an acceptance of the misleading way that methane and carbon equivalents are taken account of.

The sector needs to strive to reduce footprints via improved efficiency measures and, while more holistic footprinting tools are required, the government needs to press forward with ambitious incentives and rewards for a broadening range of environmental and social outcomes. The ultimate aim should be that this is incorporated with wider sustainability metrics to understand optimum balances and possible trade offs.

Accepted and reliable definitions, measurements, indicators of holistic sustainability and critical baselining are needed to enable assessment of performance and ability to manage individual farm business risks. Proper and adequate reward must be provided for public goods delivery based upon these measurements. Income foregone calculations are inadequate, and even more so when assessing different sections of the stratified sheep system.

For example, hill and upland systems are unable to compete on a lambs produced per ewe basis when compared to lowland systems due to challenging topography, harsher climate, shorter growing season and disadvantaged land that has been recognised by policymakers as having lower levels of soil fertility. But the hills and uplands have greater potential to deliver public goods and services over and above food production while supporting rural communities (as discussed in chapter 3.6).

A tunnel-vision focus on just carbon or nature recovery alone ignores the essential role of livestock farming and these communities and businesses. These additional benefits need to be included in sustainability assessments, demonstrating the need for holistic metrics and assessments.

Figure 4. Changes that individual consumers can make to reduce their carbon footprint. Adapted from Ivanova et al., 2020. [220]

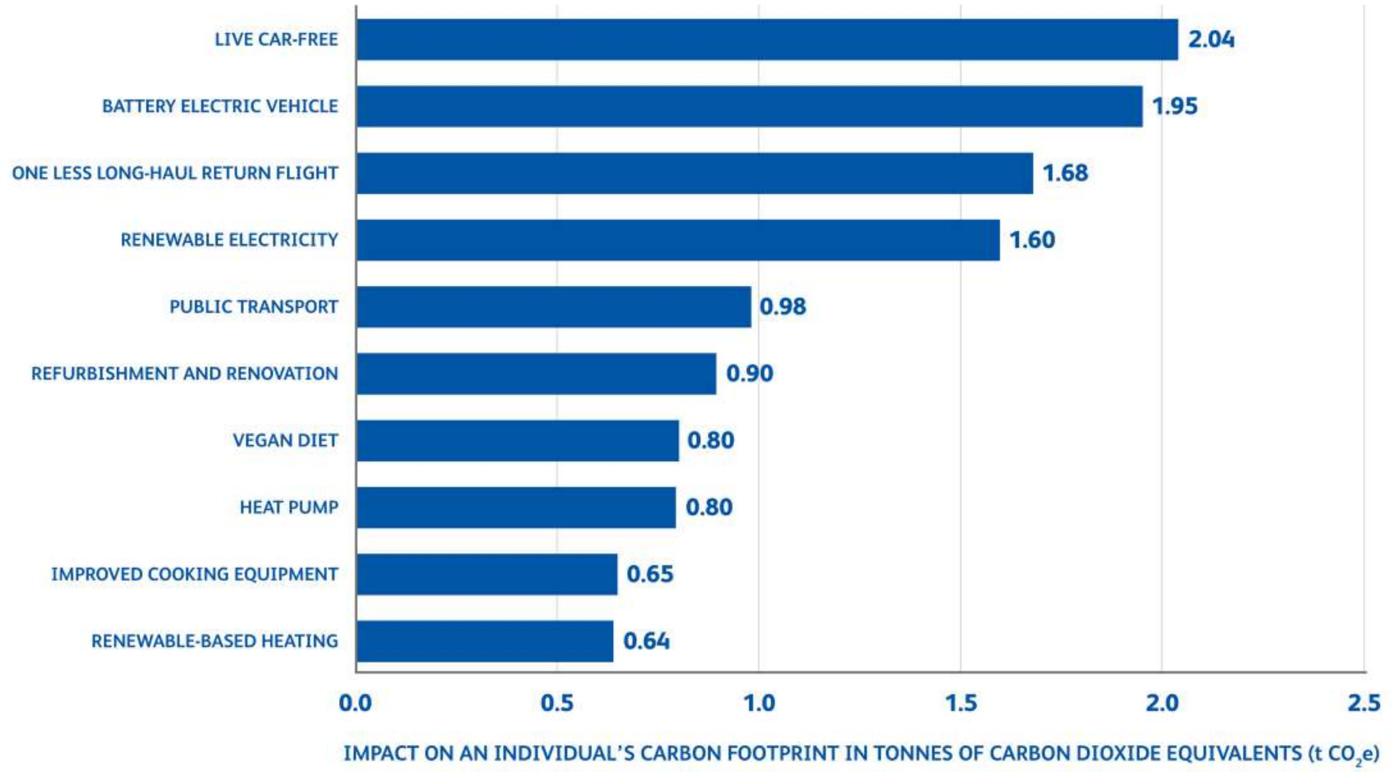


Table 5. Different carbon footprint tools currently available to assess UK sheep systems

TOOL	SPECIFIC TOOL STRENGTHS	LIVESTOCK OR CROP-FOCUSED?	DATA INPUTS	COST
Agrecalc	Complex tool that assesses carbon across whole farm and per enterprise. Includes sequestration.	Both	By producer	Free for farmers
Cool Farm Tool	User friendly with focus on productivity.	Greater focus on crops	By producer	Free for farmers for up to five products
Farm Carbon Toolkit	Carbon sequestration and crop/soil emissions.	Greater focus on crops	By producer	Free for farmers
Sandy (Trinity AgTech)	Measures biodiversity and water as well as carbon	Both	Producers, plus data from other apps	Paid subscription

CHAPTER 5

Future progress: the challenges and solutions

The agricultural industry is unique in that while still being a contributor to greenhouse gas emissions – about 10 % of all UK emissions[231] – it also has the potential to mitigate climate change by acting as a carbon sink removing the main greenhouse gas (carbon dioxide) from the atmosphere within soil and vegetation.

Farmers, crofters and land managers are therefore given the dual challenge and opportunity of reducing greenhouse gas emissions – directly from livestock and fossil fuels and indirectly from input application and manufacture – and maintaining food production, while also increasing the amount of carbon being sequestered into soils through peatland restoration and plants including trees and hedgerows.

But to achieve this there are a range of challenges to overcome, with pressing questions around viable markets; private and public finance for delivery of public goods; food security; food self-sufficiency; food sovereignty; healthy diets; climate change; nature loss; soil, air and water quality; biodiversity and health and welfare of farmed animals.

There are also a range of attitudes and practices employed in maintaining and enhancing the environment with considerable variation in objectives and opinions between sheep farmers in relation to providing habitats for nature, protecting natural resources and reducing greenhouse gas emissions.

Sheep farmers generally have a strong and positive interest in the environment in its widest sense, although there are differing views about what constitutes a good environment across sectors. In many cases environmental management and food production have become polarised objectives, with policies and attitudes swinging from one to the other as an either/or issue. The opportunity now arises to set a more balanced list of objectives, recognising the equal importance of food production and environmental management working in concert.

In recent years the polarisation of approaches to food and farming has pushed policymakers to support either land sharing or land sparing, but this isn't an either/or issue; it should be a balance of both depending on resources and objectives. Even on extensive sheep farms where land sharing between farming and many other interests is commonplace, some land will be spared, whether this is for hedgerows, trees, or wetlands.

With 71 % of Britain's land area managed through farming, it is vital any future frameworks for nature and new environmental targets have farmers at the centre of the decision-making process. Frameworks must be flexible and enable choice in delivering environmental protection while ensuring food production and UK food security are not overlooked.

The significant but often unrecognised progress UK agriculture has made towards becoming more sustainable must also be acknowledged. For example, there has been a significant reduction (17 %) in greenhouse gas emissions since 1990, and a 3 % reduction in emissions from the agriculture sector between 2019-2020. Emissions in the UK from: transport (24 %), business (18 %), residential (16 %) and energy supply (21 %) were all higher than agriculture (11 %) in 2020[231]. But, as these sectors de-carbonise, hopefully at pace, agricultural emissions will have to be increasingly off-set through land management (carbon nature-based capture).

Increasing levels of involvement in agri-environment schemes such as Countryside Stewardship and the introduction of the newer sustainable farming schemes across the nations will play an ever-increasing role. Public and private environmental schemes need to be designed to ensure the active farmer is the recipient beneficiary, using a Tenants' Commissioner to ensure fair play between landowners and tenants.

For example, Landscape Recovery Funds involve groups of farmers (including tenants) working collectively to deliver a range of environmental benefits across rural landscapes to increase biodiversity, improve water quality, reduce flood risk and help achieve net zero targets.

As of summer 2023, these projects – covering 40,000ha – had restored and protected 700km of rivers to provide habitats for 263 species including rare species such as the water vole, otter, pine marten, lapwing, great crested newt, European eel and marsh fritillary[239, 240].

These programmes actively require farmers and land managers to improve and enhance biodiversity on farm while also producing food and fibre. Evidence of the preparedness of farmers to engage in environmental improvements comes from the high level of uptake of the environmental schemes. For example, in January 2023, there were around 32,000 countryside stewardship agreements, a 94 % increase from 2020. There are also 2,307,258ha of mapped priority habitats in England, with around 46 % of these in an agri-environment or woodland scheme[239].

The Farming in Protected Landscapes Scheme (2021) has created and improved more than 70,000ha of habitat for biodiversity, planted more than 100miles of hedgerow and more than 100,000 trees and conserved or enhanced 300 historic features, buildings and structures as well as restoring eight miles of dry-stone walling. Uptake of these interventions demonstrate a willingness and drive by producers to do what's best on their farm, resulting in a holistic sustainability, helping the sector to become more sustainable and deliver on net zero targets while improving food security.

Policy

The UK Government and devolved administrations have signed up to their own legally binding climate targets and, although agriculture is in a unique position to offset its own emissions, there is a lot to do to get to get there.

Governments must provide a clear vision, long term direction and invest adequately in programmes that improve sheep farming efficiency, reduce environmental impacts and provide an encouraging landscape for both those in business and future farming generations. This requires agricultural and environmental strategies that go beyond parliamentary terms.

Policies should also do more to be ahead of the food, fibre and environmental challenges that lie ahead, rather than dealing with emergencies as they occur. This will require partnership working and consensus building around future trade policy, and reconciling and balancing views on national and global food security and self-sufficiency. Food, farming, environment, health, and education policies should be more aligned with a commitment to avoid contradictions and conflicts in policy direction.

The lack of clarity and connectedness in agricultural policy development from the four UK administrations is concerning. It risks an unlevel playing field for farmers and a lack of strategic direction in tackling health and disease challenges. There is inadequate sharing of information or adoption of approaches that are shown to work well.

Sheep farmers want and should have the opportunity for informed discussions with decisionmakers, ensuring the aims and implementation of future agricultural policy is relevant, evidence-based and applicable. It is important future policy targets and/or ambitions are based on science and supported by evidence, recognising the significance of farmers in achieving any proposals set out by policymakers. Any agreed

CASE STUDY: **Kevin Harrison**

280 wool-shedding and 160 higher input ewes on a 480-acre mixed hill farm in Gloucestershire

Reducing both human input, expenditure and a reliance on bought in feed was the driving force behind changes made by Kevin on the farm he manages in the Cotswolds.

He used to run 900 North of England Mules in an intensive feeding, early lambing system. In order to get a better work/life balance, he decided to reduce numbers, change the breed and is now embracing the easier care concept. It has led to reduced feed and labour, fertiliser, energy and medicine inputs.

"My mental and physical wellbeing has improved, as the physical strain of weighing lambs every week and filling feeders was huge," he says. Kevin only began the transition process last year but is hoping to eventually have a closed flock of 550 Exlanas with minimal input and the ability to take on environmental schemes due to the new sheep management system.

"It requires a completely different understanding of parasites, timing of treatments, understanding SCOPS from a grazing perspective versus indoor, and getting a handle on the opportunities and challenges of year-round grazing," says Kevin.

Kevin is aware the farm is contributing less to food security but would value a holistic sustainability tool to allow him to better understand the outputs of the farm.

targets, outcomes and actions must involve the people and businesses that will deliver them, making farmers and land managers ideally placed to deliver such outcomes. Their knowledge and experience on the best delivery methods working alongside food production should be recognised.

Significant changes to land management must be pragmatic and practical for farmers, developing mechanisms to enable farmers to be practically engaged in conservation works. Where farmers can benefit financially from these works they will become stronger stakeholders.

There needs to be a fine balance, without compromising food production. Some advisers are recommending wall to wall high value farming scheme options that take the focus away from balanced farming systems. Long-term land use change to encourage environmental benefits only displaces agricultural production on farmland, potentially adding to the environmental footprint of production in other trading nations. NSA encourages programmes to be tested and trialled before wider rollout.

With sheep farming being mainly grass-based and extensive in nature, sheep farmers are in a unique position where they can offset on-farm emissions through sequestration[230] and do more to improve natural resources and provide for a farming related nature. Carbon trading is in its early stages but this should not create conflict between landowners and tenants, or rights holder and owners of common land.

Farmers and policymakers should also be careful not to sell off carbon rights if that carbon is needed for achieving net zero. The current mechanisms around carbon auditing, offsetting and trading are inconsistent and uncertain, with an absence of accreditation standards, something which must be immediately addressed before pushing land managers to trade carbon. Food production and food security in the UK should not come at the cost of other polluting industries buying and offsetting their emissions.

There is evidence of landlords and landowners choosing to take land away from graziers and out of farming and focus on environmental delivery only, reducing land availability for tenant farmers and graziers. The lack of land/farm ownership can also act as a direct barrier to implementation of sustainability actions. Short term tenancies discourage investment in infrastructure or land management-based actions, as the tenant farmer doesn't reap the benefits and is at risk of landowners or subsequent tenants being rewarded.

The importance of tenant farmers is highlighted in the Rock Review, which states tenant farmers must be 'properly integrated into future farming policy, the design of all future schemes and supported for long-term resilience of the sector'. It goes on to say tenant farmers 'are and must 'remain a crucial part of the future agricultural and land management landscape'. The report also highlights the challenges faced by tenant farmers, including rent requirements, short duration tenancy agreements, restrictive clauses, and contractual issues. With 45 % of farms in England alone being tenanted or a mixture of owned and tenant[182], this poses a corner and the outcomes of the Rock Review must be implemented in full, including the creation of a Tenants' Commissioner.

In an ever-changing marketplace and volatile political landscape, it would make sense for any proactive steps towards increasing and maintaining sustainability to be incentivised. Current large costs placed on farming businesses mean additional costs associated with sustainability could be counterproductive.

CASE STUDY: **John Yeomans**

540 breeding ewes and 180 ewe lambs plus sucker cows on 275 acres of hill in Powys

Making the farming pay to allow conservation work to continue is important to John, his wife Sarah and children Tom, Jack and Joe.

"Over the years we have planted more than 40,000 hedge and tree plants and renovated and planted new hedges. We believe productive farming and conservation work go hand in hand," says John.

The family is constantly trying to improve the farm in all ways – leys for their sheep to improve grazing, looking at different seeds mixtures, carbon capture, optimising production, best practice parasite control, lamb and beef boxes sold off farm and using a solar water pump on one hill block to aid grazing.

"We started rotational grazing in 2014 after the dreadful spring of 2013. That has had quite an impact on our farming, but of course it is certainly not for everyone," says John.

Utilising technology is another area to aid sheep system sustainability. But as with new technologies, adoption needs to be encouraged ideally through capital grant aid and linked with training opportunities and incentives. Demonstrating the benefits of adoption on profitability, productivity, efficiency, animal health and wider sustainability will undoubtedly aid uptake. Farmer to farmer learning is the best method for encouraging adoption, increasing the ability to fully understand the cost/benefit associated with the various technologies. By making technologies more affordable, cost efficient and simple to use, uptake will increase and overcome this barrier.

Much of the current technology and tools available incur large costs and the lack of benchmarks makes interpreting the results difficult. By making technologies more affordable, cost efficient and simple to use uptake will increase improving system efficiency. Technology such as increased use of faecal egg counts, better use of EID and livestock information service, disease screening and health monitoring programmes, and the use of current and new vaccines are already being deployed to be more efficient and productive, reducing greenhouse gas emissions and carbon footprints, and contributing to global One Health commitments.

Further government investment in technologies such as drone or satellite technology, LIDAR remote sensing, vaccine development and licensing, PCR testing for disease and parasite screening, food traceability alongside innovation and government-supported extension including knowledge exchange would help increase understanding and aid adoption in the sheep sector.

It must also not be overlooked that there are still only 24 % of farming business with access to super-fast wifi with a staggering 30 % still managing on speeds less than 2mbps, making access to resources a potential barrier[244].

Food security

In order to become more food secure, we must maintain and further enhance local supply chains alongside developing export opportunities. Our diversity of sheep breeds and sheep farming systems should be recognised as an asset with supply chains supporting that diversity (more in chapter 3.6), providing infrastructure and legislation that protects and provides opportunities for UK producers, in turn affording them with the ability to reinvest in delivering high environmental and animal welfare outcomes.

The protection, enhancement and opportunity of food supply chains across the UK should be equally prioritised within environmental land management across governments and there should be sufficient investment in processing and storage infrastructure in a way that provides resilience in food supply chains with a low carbon footprint.

Self-sufficiency is not the same as food security. Food security might be best achieved by being part of a global food system. But the UK's ability to be food secure can be argued to be underpinned by a high level of self-sufficiency, which will help protect us in a volatile world where politics, economics and climate can easily and quickly change the global food system.

Recent challenges such as the covid pandemic and the conflicts in Ukraine and Gaza have highlighted the vulnerability of UK food security should governments continue to prioritise imports and not support domestic production. Therefore, there is a critical need for UK produce – being world renowned for its high environmental, welfare and health standards with a huge number of these standards being entrenched in law – to be at the heart of any future food, trade, health and environmental policy to ensure UK food security.

The current limited certainty about future trade and markets, regulation and support is a concern and the sheep sector needs the government to uphold the integrity and values of UK produce before opening the door to produce that might not be produced to the same standards or values. With a population that is continuing to grow across the world, it is argued there is a need, alongside reducing food waste, to increase food production to feed the world. But a continued need to reduce the environmental impact for food production provides further challenges.

In many cases, environmental outcomes and the preservation of natural resources are being seen as more important than food production, and new environmental schemes are risk-free in comparison with producing food for a volatile market and uncertain climate. There needs to be proper reward for delivery of public goods but policies that don't undermine the ability to produce food sustainably are needed. Otherwise, there may be less UK-produced food, putting the country at risk of becoming reliant on imported food that can carry a higher carbon footprint depending on production system.

In addition, with increasing living costs already affecting diets, particularly for lower income households, utilising homegrown produce is central to being a more food secure nation. Replace imports where possible and providing support and legislation that protects and provides opportunities for primary UK producers will pay dividends.

This brings the debate back to the needs for holistic assessments when producing agricultural policy. For example, because methane is a less long-lived greenhouse gas than carbon dioxide, it is argued a 10 % reduction over 30 years is equivalent to methane net zero, and this initiates thoughts about reducing livestock numbers as a quick fix to achieve this target (see chapter 4). However,r a reduction in production capacity at a time when food needs are increasing will result in the UK being less food secure, more reliant on imports over which we have questionable impact influence, and a greater disconnect from how food is produced, and not preparing to be resilient against climate related disruption, political unrest or resource limitations.

The UK should aspire to increase its food self-sufficiency levels within environmental boundaries, increasing productivity and minimising loss and waste. Sheep farming produces a high-quality protein (mainly meat) from land often unsuitable for other forms of food production), and in lowland situations is increasingly becoming recognised as being a central part of regenerative cropping rotations and building soil fertility.

Reducing production capacity negatively affects UK food security so there is a need for better integration of farming and environmental features and policies that avoid unintended consequences and short-term gain. In essence, food security as a public good alongside environmental stewardship.

Market support

Provenance is a key selling point for UK lamb exports and supports the ambition to eat less meat but of better quality; selling the sustainable, natural story but one which should be more widely supported domestically.

The UK produces a unique variety of sheep meat with variations in flavours from the diverse breeds across the country, but consumer awareness and accessibility to sheep meat of different ages (lamb, hogget and mutton) and of known breed and provenance is low.

Most people eat lamb as an occasional treat, wrongly disregarding it as difficult to cook. Levy bodies have been working hard to dispel this myth and schemes such as British Heritage Sheep are making an asset of diversity within the sheep sector (which has a close relationship with the environment), seeing it as a unique selling point for diverse tastes and textures in the sheep meat. This is being adopted by some farms to target premium markets.

Support in this area to raise awareness, increase consumer value of provenance, dispel cooking myths and encourage more supermarket space to embrace the diversity of our sector would boost domestic sales and provide a point of interest in some of our export markets, changing the position of competing in a commodity market.

Policies and markets should support localisation given that it suffered during a period when globalisation and competing at a commodity level was an objective (the shortcomings of which are now increasingly recognised), including specialist products and short supply chains that deliver value for specialist products with high levels of provenance as this reduces food miles, aiding sustainability.

Overall, the sheep sector needs more investment in market development (for breeding stock, health status and for finished food and fibre products), and proper financial reward for public goods delivery that is index linked, recognising the strength of a broad range of market opportunities, and indeed the diverse range of market opportunities that exist including supermarkets, high street butchers and farm shops, halal and export markets, Export markets are estimated in 2024 to add some £40 a head for sheep values due to competitive prices and improved carcass utilisation.

Attitude and adoption

There is a need for adoption of innovation and good practice and a willingness to change away from farming in the same way over multiple generations. This is already happening and farmers have always shown they can be great innovators – but adoption of appropriate technology and good management is slower than the pace of change in today's world.

An unwillingness to change can sometimes be a barrier, so regular communication and contact with others is needed to encourage strong, credible relationships[244]. This will be further enhanced if approaches that divide food production from environmental protection are avoided and there is recognition that sheep farming is a multi-functional activity and has ways, at varying levels, of balancing production with environmental and landscape management.

How can we aid adoption of practices that advance sustainability without losing the essence of what is fundamentally an industry founded on sustainable practice? Knowledge exchange on its own does not lead to successful adoption. There is a need for consistency, follow-up and on-going support for successful adoption and for this to be maintained. Awareness, education and ownership of the challenges and the solutions needs to be prioritised. Governments should have a focused role in ensuring this, give that agriculture will play a vital role in delivering public goods, food and helping to reach net zero targets, and that farmers are equipped with all the information, guidance and training they need.

REPORT CONCLUSION

While people actually make things happen, government policies arguably have the biggest impact on farming and land use.

Britain's exit from the EU presented the opportunity for new policies to support environmental, social and food needs, but it took serious disruption in food supply chains during the covid pandemic and the conflicts in Ukraine and Gaza for policymakers to wake up to the fragility of our food security and availability.

The frailty of an approach putting environment into a public funded box and leaving food to the vagaries of an increasingly global marketplace must now be acknowledged. Agricultural policy needs to be long term, provide stability and clear direction with the ability to fine tune policies quickly, recognising the multiple challenges but accepting the interconnectedness of a healthy planet, healthy ecosystems and healthy people.

NSA key asks: Delivery

- Clear scheme and policy objectives, with truthful, honest and in-depth monitoring of outcomes and broad sustainability metrics.
- Pre-rollout testing, monitoring and evaluation of new land management schemes and any system that places financial value on carbon credits and biodiversity.
- Environment work at a scale and with operational procedures that encourage delivery by farmers and local contractors, supporting local rural economies.
- Farm schemes to cover carbon footprinting and sustainability assessment costs.
- Farm schemes to include capture of core data, with investment to enable it to be utilised nationally in an anonymised/aggregated way.
- Incentives and encouragement for wider uptake of health monitoring schemes.
- Legislative changes to permit proven technology and tools to reduce pain at castration and tailing.
- Support for adoption of UK wide health and disease strategies.
- Recognition of the value of the Register of Sheep Advisers (RoSA) in advice provision.

NSA key asks: Strategic and directional

- A clear long term vision and strategic direction for UK agriculture, food and land use, including species introductions, at a national and local level, within broad sustainability targets and with agreed goals and adequate funding.
- Food production to be recognised as being of national strategic importance and accepted as a public good.
- Sheep meat imports required to be of an equivalent standard, to raise global sustainability outcomes.
- Within existing trade deals, measures to avoid market disruption to be tested and then employed when needed.
- Exploration of a new Sanitary & Phytosanitary Health Agreement with the EU, to aid EU trade and reduce disease risk from illegal imports.
- Recognition of potential trade-offs between various sustainability objectives and a move towards simple but broad sustainability assessments.
- Replication of the independently chaired Land Use Group as recommended in the Dartmoor Review for other sensitive and contested areas.
- A review into the strategic importance of UK vaccine production and the risks to health, welfare, food production and carbon footprints of unreliable vaccine supply.
- Commitment to ongoing financial incentives to maintain and further improve health and welfare of farmed animals.
- A focused review of carbon sequestration opportunities presented by sensitive farming and related cropped and non-cropped habitats.

THE FULL VERSION OF THIS REPORT, CITING SOURCES FOR ALL THE INFORMATION INCLUDED, IS AVAILABLE AT www.nationalsheep.org.uk/our-work/policy

This report demonstrates the importance of holistic thinking and recognising multifunctionality, valuing what we have and enabling us to highlight strengths, weaknesses and acceptable trade-offs, that vary between regions, counties and farms.

Sheep farming has been criticised for being non progressive, failing to make the technical progress observed in other livestock sectors. This report identifies clear challenges, but the sector has been right to resist calls to reduce genetic diversity or intensify beyond on-farm resources. As an industry, we have been right to maintain our free range and grass-based systems and to persist through tough economic times.

The UK approach to farming sheep aligns with regenerative interests both in the uplands and lowlands. Sheep are free to enjoy a life close to nature; farmers are focusing on reducing inputs and striving for responsible medicine use; and management practices aim to build soils and sequester carbon while reducing emissions and delivering for the environment. Most sheep farmers are involved in ways to improve their systems, through a combination of genetics, nutrition and health, reducing waste and adding value.

But for all the positives we still have a long way to go. We need to encourage adoption of good practice and efficiency measures, and the use of basic records providing data to support evidence-based decisions. There is more we must do to reduce energy use, methane emissions and carbon footprints. There are many opportunities to make more space for nature and improve water quality. Our ecosystems are best supported from the ground up and while there is talk of reintroducing apex predators around the country, this would only work with a clear mitigation strategy. There are plenty of non-contentious species we can support.

We need schemes that encourage profitable and resilient food production to be at the core of sustainable land management, providing and encouraging investment in true sustainability. Schemes that support small and medium scale processing and innovation and give long term confidence in protecting the environment and supporting communities – including recognition of healthy food production as a public good. We need a better means to communicate all this and integrate with education and advice on health and wellbeing, and sometimes we need stricter regulations that enforce responsible use of the countryside.

We are blessed with intelligent and enthusiastic young people coming into our industry, many of whom are supported through the NSA Next Generation programme offering education, hands on experience and access to a wide range of expertise. Collectively, we need to shoulder responsibility to own the challenges we face, to be enthusiastic about the environment, nature and improving sheep welfare, encouraging the next generation as much as we can.

The market can play its part too. Levy bodies recognise the importance of trade development and the need for positive reputation and promotion of UK produce. Markets can drive improvements but we must protect our domestic market against imported alternatives not produced to our standards and values. It's incompatible to think we can operate to some of the highest regulatory requirements and have a cheap food culture.

NSA would not be doing its job responsibly, nor would we be taken seriously, if this report didn't highlight the areas where we can improve. But this report also shows UK sheep farming has a sound base to remain sustainable for the future – fantastic nutritious food, renewable fibre, and leaving in its wake an attractive environment enjoyed by all.

The facts presented are evidence based thanks to the work of the School of Sustainable Food & Farming at Harper Adams University. NSA would also like to thank all the farmers who have enthusiastically contributed case studies. As a grassroots farming organisation, no NSA publication would be complete without your help.

NSA key asks: Development and innovation

- Development of a farmer decision tool to assess the impact of potential management changes and scheme involvement.
- Establishment of a national livestock gene bank with a dynamic storage strategy.
- Expansion of farm support schemes to fund whole lifecycle carbon assessments and sustainability footprinting, and also drive data recording to support performance advances.
- Development of products and markets that make a virtue of systems diversity.
- The establishment of sustainability/environmental indicators to support breeding values.
- Harmonisation of the key metrics of carbon calculators with reporting including GWP_{100} and GWP* and on a per kg of output and per hectare basis.
- Development of recognised methods of sustainability assessments across a broad set of metrics.
- Appointment of a tenants' commissioner with commitment to progressing with the recommendations of the Rock Review.
- More investment in identification of reliable genetic markers for key diseases.
- Investment in small scale/non disruptive farm based renewable energy production.
- Innovation and investment in of wool.

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