

RASE
**FARM OF THE
FUTURE**



JOURNEY TO NET ZERO

A guide to action



Produced by
Innovation for Agriculture on
behalf of the **Royal Agricultural Society
of England (RASE)**. Funding for the
creation of this guide has been
gratefully received from the
**Esmée Fairbairn
Foundation**.



WHY HAS THIS GUIDE BEEN CREATED AND HOW SHOULD I USE IT?

What will the farm of the future look like? With a wide variety of UK farm businesses, there is no 'one size fits all' approach, but there are already many 'tools in the toolbox' to decarbonise the UK's food supply chain and help meet net zero targets.

Based on RASE's 'Farm of the Future' report, this guide highlights some of the tools available to farm businesses. It shows how farmers can be part of the transition to a more circular economy, improve soil management, deploy solutions to sequester carbon, protect rural resources, and adopt on-farm renewable energy.

The actions outlined in this guide are grouped into three sections: action that can be taken immediately, actions that require some planning and long-term options to consider. All farmers can contribute towards meeting net zero in UK agriculture.

Each of the actions featured has a short description followed by a QR code and page number to access the relevant section in the main Farm of the Future report or associated technical papers.

HOW WILL THIS GUIDE BENEFIT YOUR FARM BUSINESS?

This guide provides a snapshot of the systems which might feature on farms of the future. It is split into three sections:



1. Act Now - Demonstrating pathways to success through simple steps that you can take now and in the future, with signposting to further details in the main Farm of the Future report.



2. Start Planning - Indicating what's coming, allowing you to further research options relevant to your enterprise.



3. Think Ahead - Helping you to prioritise which action to take and when – and where to find more information



A PREFACE FROM LORD DEBEN

CHAIRMAN OF THE UK'S CLIMATE CHANGE COMMITTEE (CCC)



“There is no way in which we can win the battle against climate change unless we recognise the central role which agriculture must play. Net zero is not just a matter of radically reducing our emissions. There can't be human or animal life without emissions. Zero has therefore never been on the cards. However, before the industrial revolution, the earth - through oceans, soil, and trees - sequestered enough of those emissions to maintain the climate patterns which made human life possible. That was the balance of nature with which we have interfered both by massively increasing our emissions and by reducing the earth's capacity to sequester. We have cut down our forests, polluted our oceans, and degraded our soil. No longer can the planet absorb what we emit.

The 'net' bit of net zero is therefore vitally important and crucially it's largely in the hands of farmers. Whatever we do to regenerate our seas, to stop deforestation and to halt the march of the deserts, the most important job will be to learn how we feed the world without costing the earth. We have to regain the fertility of the soil, plant and care for many more trees, recreate the hedges we have lost and at the same time produce the food which a growing world population needs. Food production is the first of all 'public goods' that farmers offer. But it has to be done in a way which also leads to net zero.”

CONTENTS

The principles behind regenerative agriculture.....	V
---	---



ACT NOW 1

Carbon auditing.....	2
Regenerative agriculture: management plan.....	3
Mob grazing and diverse leys.....	4
Cover crops, catch crops and green manures.....	5
Autonomous dairy systems.....	6



START PLANNING 7

Companion cropping, intercropping and integrated pest management.....	8
More efficient land-use: arable.....	9
More efficient land-use: livestock.....	11
Animal health and welfare.....	13
Feed additives.....	14
Genetics.....	15
Organic fertiliser treatment and applications.....	16



THINK AHEAD 17

Smart farming.....	18
Future farm energy production.....	19
Delving deeper into farm-scale anaerobic digestion.....	20
Energy storage technology and uninterrupted power supply.....	21
Assessing and adopting net-zero fuel options.....	22
Autonomous vehicles.....	23
Automation of fruit and vegetable sector.....	24
Novel protein sources.....	25

Promoting biodiversity: an equilibrium between farming and nature.....	26
What does future policy look like?.....	27
Summary.....	29





THE PRINCIPLES OF REGENERATIVE AGRICULTURE

Regenerative (regen) farming methods restore soil health, improving the soil's ability to sequester carbon and its resilience to drought and high rainfall events. Improving organic matter and soil biology reduces the inputs required to provide crops with the nutrients they need to grow. Many of the actions included in this guide stem from the principles behind regenerative agriculture.



Minimise soil disturbance

- Soil seed bed cultivation is not always necessary, especially to conventional depths of 15-20 cm
- Reducing frequency of physical and chemical soil disturbances benefits the soil structure, biology, water infiltration and retention rate



Keep soil covered

- Living plants and/or crop residue protect soil from surface erosion, compaction, poaching, baking, freezing, surface runoff and nutrient loss, whilst promoting enhanced biological activity in the soil



Maintain living roots for as much of the year as possible

- Living roots provide a lifeline for soil biology. If a living root is active within the soil, nutrients are circulated and carbon is captured



Promote diversity

- Diversity initiatives can include companion cropping, intercropping, diverse leys, catch and cover crops
- Different species provide a multitude of above- and below-ground benefits; root depths, nutrient mining, N-fixation, C-sequestration, biological synergies, crop value, yield, forage, improved health and welfare



Incorporate livestock

- Introduction of livestock to arable land will turbo charge soil biology.



Farm of the Future report, page 21

Most agricultural soils are degraded to some extent, but they can be rapidly improved following the adoption of regenerative farming practices. Anecdotal evidence suggests that regeneration to a meaningful degree can be achieved in as little as 5 to 7 years, although this can take longer in some soils.



Graphic courtesy: Paul and John Cherry, Groundswell

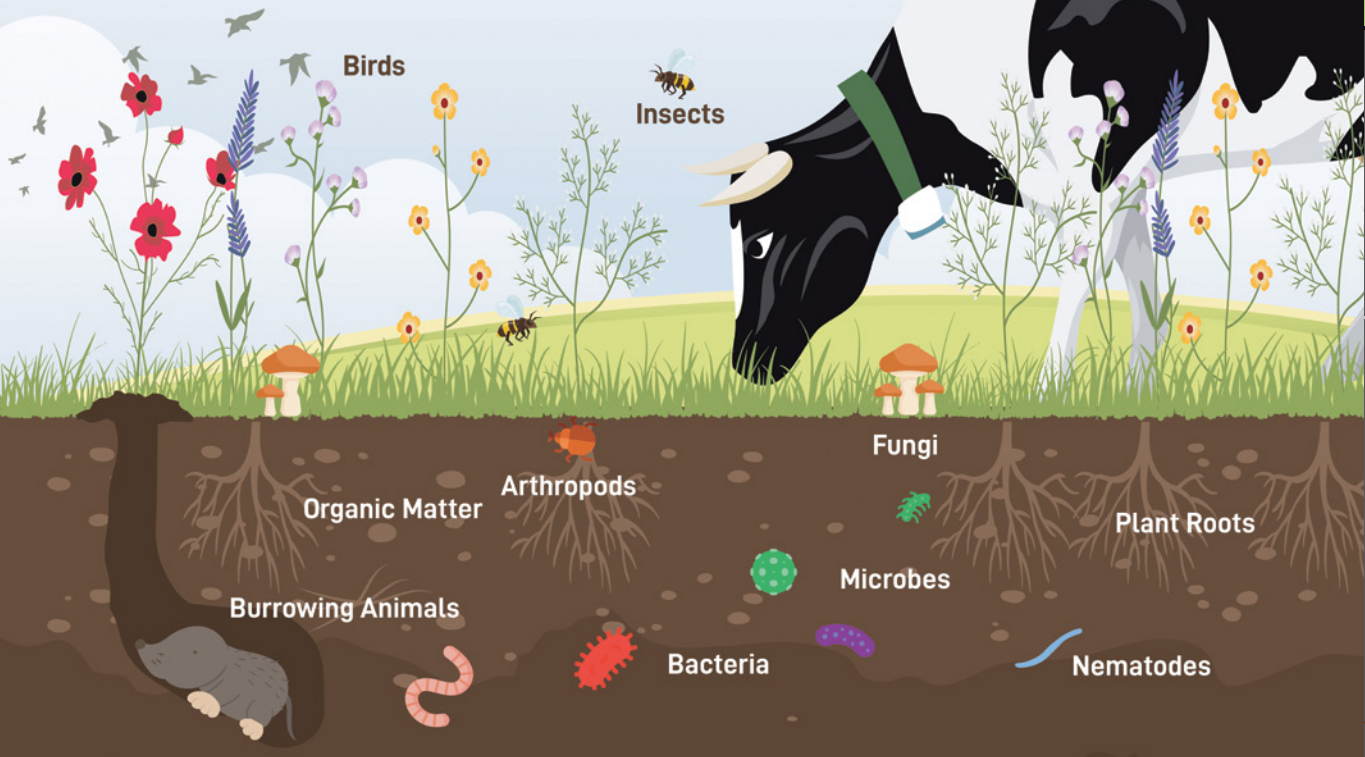


ACT NOW



1. Carbon auditing
2. Regenerative agriculture: management plan
3. Mob grazing and diverse leys
4. Cover crops, catch crops and green manures
5. Autonomous dairy systems

The 'Act now' section of this guide aims to demonstrate straightforward and practical steps that can be taken now to reduce a farm's carbon footprint. Many farmers may already be implementing some, if not all, of these actions. There is no single silver bullet to reduce greenhouse gas (GHG) emissions significantly. A whole farm approach which selects multiple actions suitable to the specific enterprise will have the biggest impact and longevity. In this section are a selection of possible 'quick wins' to start decarbonising a farm business.





ACT NOW

CARBON AUDITING

Carbon metrics are an essential tool that farmers can use to identify climate solutions, to baseline the farm's emissions and to inform decision making.

Absorbing more carbon than the farm emits is a goal that all farms can work towards, but identifying the carbon footprint of the farm business is the first vital step.



A carbon audit identifies the source and quantity of carbon dioxide, methane and nitrous oxide emitted from the farm, in addition to the carbon sequestered in the soils, hedges and woodland, as well as any other sinks. This highlights areas where improvements or changes can be made.

Reducing carbon emissions in a farming business makes sense on many levels. High emissions tend to be linked to high resource use and/or wastage, so reducing emissions also tends to reduce costs. This makes the farm more efficient and should improve profitability.

As well as the business opportunities that come from reducing emissions, farmers and landowners are in the unique position to be able to sequester carbon in trees, hedgerows and margins and within the soil.

BUT WHICH TOOL TO USE...

There are several carbon footprinting tools designed for UK farmers and growers. Currently the four that are used the most are:

1. AgreCalc
2. Sandy
3. The Cool Farm Tool
4. The Farm Carbon Calculator

Keep in mind that the methods used by each calculator are different, so comparing assessments from different providers may skew your results.



Farm of the Future report, page 26-29





ACT NOW

REGENERATIVE AGRICULTURE: MANAGEMENT PLAN

A management plan is a tool that can improve the effect and efficiency of the transition towards regenerative land management and the farm's future. This tool should include the farm's vision, aims and objectives, the strategies used to meet those objectives and evaluation methods used to measure performance. This could include short-, mid- and long-term initiatives, with an action plan and timeline of when those actions need to be completed by.

To consider ...

- Soil assessments
- Geographical field mapping
- Long-term rotation plans
- Farm-to-farm knowledge exchange
- Controlled traffic farming
- Financial plan
- Nutrient management plan
- Soil management plan
- Livestock integration plan
- Integrated pest management plan.

DID YOU KNOW....

Stable soil organic matter (humus) can absorb six times its own weight in water. It also supports other microscopic soil dwellers which help to create a sponge-like soil structure with capacity to absorb rainfall more effectively, helping to prevent flooding while mitigating the effects of drought. In many cropped soils in Eastern England, soil organic matter levels are as low as 3%, restricting infiltration, drought resilience, nutrient cycling and long-term productive capacity. Soils vary enormously, but nearly all are improved by increasing their carbon levels using regenerative farming methods.



Farm of the
Future report,
page 21-43





ACT NOW

MOB GRAZING AND DIVERSE LEYS

Grasslands are a vital ecosystem, covering 40.5% of terrestrial land area (excluding Greenland and Antarctica). The concept of 'Mob Grazing' comes from grazing animals on the great plains of Africa and the Americas. Tight groups of ruminants, kept together in a mob are rotated around different paddocks, intensively grazing small sections of pasture for a very short period (e.g., 0.1 ha/24 hr).

Moving regularly provides ruminants with a diet which is balanced in terms of plant maturity, dry matter and protein content. Roughly a third of the pasture is grazed, a third trampled and a third remains to regenerate. The crop residue provides a protective blanket and feedstock for soil fauna.

DID YOU KNOW....

Greater plant diversity within the pasture provides plant disease buffering, nitrogen fixation from legumes and varied rooting depths which hosts a multitude of benefits. The reintegration of legume-rich leys to arable rotations brings multiple benefits by improving soil structure and organic matter content - enhancing nutrient and water use by the following crop and improving climate resilience.



Steps that could be used to establish diverse ley paddocks for mob grazing

1. Choose fields – account for soil type and characteristics
2. Select seed mix – to your preference and requirements
3. Graze, mow and/or terminate competition
4. Prepare seedbed – adding organic materials such as manures where necessary
5. Drill or broadcast seeds – roll to create seed to soil contact
6. Leave to establish – can lightly graze at ~6-8 weeks to promote tillering
7. Rotationally graze in temporary paddocks – leave sufficient recovery time.





ACT NOW

COVER CROPS, CATCH CROPS AND GREEN MANURES

The estimated annual cost of UK soil degradation is £1.2 billion per year. Currently, 70% of UK arable soils have a soil organic carbon content below 20 kg/ha or 3.4%, a 48% loss since 1940. Appropriate soil management practices will help replace the soil carbon stock.



Bare soils can lead to leaching of nutrients, particularly in the winter when there is excessive rainfall. Cover crops, catch crops and green manures are grown to make improvements to and protect the soil. They can also help with weed suppression.

These options can improve soil structure, as many of the species used produce strong root systems which aerate the soil, increasing water holding capacity and improving drainage. This will improve the soil's resilience to droughts and flooding, an increasingly regular occurrence as climate change impacts land management and farming activities.

With artificial fertiliser production and application accounting for up to 60% of all emissions associated with UK arable farming, the use of cover crops is an effective way to prevent soil nutrient losses and increase microbial activity in soils. If nitrogen-fixing legumes are incorporated into the mixes, there may even be a reduced requirement for artificial fertiliser in the following cash crop.

DID YOU KNOW....

Cover crops can sequester carbon faster than trees, making them an effective yet simple tool.

TREES

- Forestry Commission data: 16,000 trees planted under the Carbon Code
- Average carbon capture rate: 4.75 t CO_{2e}/ha/yr
- Removes 8 million t CO_{2e} in 100 years.

COVER CROPS

- Use fast-growing cover crop plants in the intervening time between crops when soils are most vulnerable to nutrient loss and erosion.
- Average carbon capture rate: 15 to 25 t CO_{2e}/ha
- 70-90 days plants accumulate above/below ground biomass.



More details can be found in the Cereals sector journey paper





ACT NOW

AUTONOMOUS DAIRY SYSTEMS

The dairy industry is already trialling and adopting a range of practices, products and procedures to help reduce its environmental footprint. These technologies can reduce waste and emissions from dairy farming activity and increase efficiencies at a farm and milk processing level.

Precision dairy farming technologies support data collection and analysis, providing valuable insights to inform herd management. The interpretation of data provided by these systems is key and can help farmers to identify the management practices best suited to their herds.

Actions or technologies with the potential to further improve efficiencies and reduce emissions in dairy production include:

- Methane-reducing additives in feed
- More targeted application of slurries and bought-in fertilisers
- Remote monitoring of cattle lameness
- Acidification of slurry to minimise ammonia emissions
- Replacement of diesel with biofuels (including biomethane produced on-farm)
- Possible supply of biogas (or biomethane) from farms to their milk processors
- On farm processing of milk for local sale – thereby reducing transport emissions
- Increased use of robotics (already well established for milking on some farms)
- Autonomous vehicles to reduce feed wastage and manage slurry.



Page 19, the
Decarbonising UK
Dairy Production
sector paper





START PLANNING

1. **Companion cropping, intercropping and integrated pest management**
2. **More efficient land-use: arable**
3. **More efficient land-use: livestock**
4. **Animal health and welfare**
5. **Feed additives**
6. **Genetics**
7. **Organic fertiliser treatment and applications**



The 'Start planning' section of the guide includes actions which can be implemented in the near future. Each action can reduce GHG emissions or sequester carbon, but these actions will require some consideration to identify which will be most appropriate for any given farm business. They may require a larger financial investment, or government support grants to help with initial cost of implementation, such as investment in machinery or technology. Consider the 'Start planning' actions and identify which stand out as realistic possibilities for your farm business.



START PLANNING

COMPANION CROPPING, INTERCROPPING AND INTEGRATED PEST MANAGEMENT

A diverse population of plants can be grown in intercropping (IC) and companion cropping (CC) systems. Symbiotic relationships between plants in CC rotations can promote resistance and resilience to pests and pathogens whilst growing at least one cash crop. Multiple crops can be grown in unison within IC rotations, providing growers with multiple products from the same land, either by harvesting at the same time and splitting by grain/seed size or intercropping with different harvest dates. There is also potential to grow crops through a living mulch (an understory of clover), providing perennial ground cover.

These types of cropping can contribute to reduced inorganic inputs, improved biodiversity and, with more emphasis on integrated pest management (IPM), fewer chemical applications of pesticides.

Other benefits include:

- Robust crop rotations ensure healthier soil and reduce weed and disease pressures
- Legumes companioned with cereals reduce artificial nitrogen requirements
- Field margin strips and in-field strips of diverse leys and wildflowers can enhance biodiversity and provide IPM benefits
- IC rotations can improve yields by 30% and buffer the risk of market shifts by securing multiple crops
- CC rotations can promote soil health, biodiversity and can reduce disease pressure, whilst increasing access to nutrients and minerals available in the soil.



*Farm of the
Future report,
pages 21, 101,
102*



*Decarbonising
cereal production
pages 9, 26*





START PLANNING

MORE EFFICIENT LAND-USE: ARABLE

Opportunities to increase the efficiency of agricultural land are becoming more easily accessible. The markets for novel crops are growing, energy crops are becoming more diverse and there is a growing market to produce seed mixes. Government policy is now encouraging better land-use efficiency, providing payments for stacking public good provisions as part of the Sustainable Farming Incentive (SFI).

Better land management is essential to mitigate global climate pressures from increasing drought intensity and frequency, as well as high rainfall events. Reducing bare fallow land, adopting regenerative farming principles and incorporating precision farming techniques can improve the productivity of arable land and environmental resilience.



Riparian woodland (at the interface between land and waterway), reedbeds and field belts create a barrier and solution to nutrient runoff, soil loss and water pollution, whilst providing an opportunity for subsidy payments.

Examples of crops and practises to improve land-use efficiency:

Novel crops

Unconventional crops with growing markets due to emerging consumer demands, e.g.:

- Pulses and ancient grains (e.g. spelt & einkorn)
- Traditional spices (e.g. saffron)
- Expanding market for crops to produce plastic-free products and materials
- Small market for herbs and medicinal plants grown at 'artisan' scale
- Growing market for seed mixes, especially for stewardship schemes
- Oats, quinoa, flax, walnuts, yellow peas, spelt, hemp and soy have increasing demand from plant-based dietary markets.

Energy crops

Low cost, low maintenance crops grown for bioenergy production. They can be used as a break crop between rotations or grown on shelter belts, riparian strips and field margins, including:

- Sugar beet, wheat and oilseed rape used to produce biofuels
- High yielding perennial crop species such as miscanthus and short rotational coppice (SRC)
- In addition to slurry and biowastes, maize and other crops for anaerobic digestion (AD) systems can be grown with companion crops. Herbal leys can also be used as AD feedstock.





Precision farming

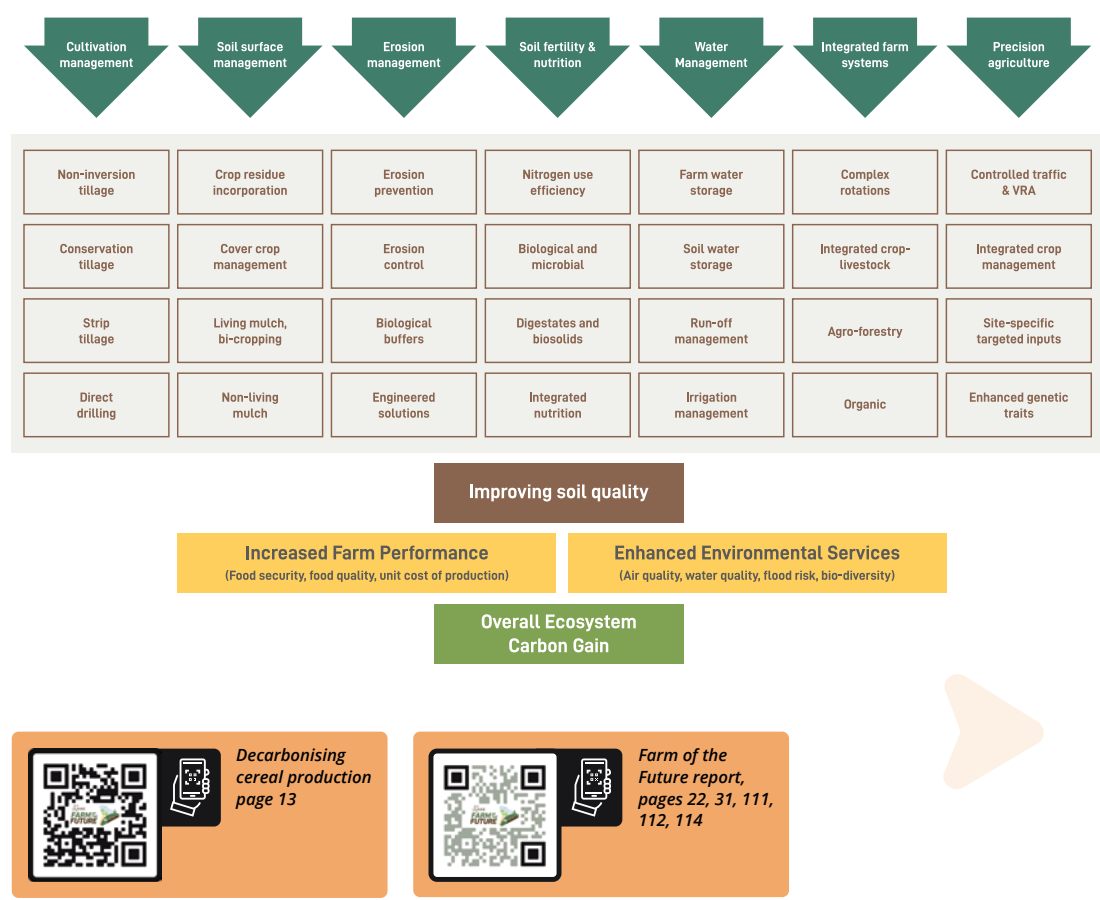
Advanced technological and data monitoring for land management, including:

- Data analysis of soil type (e.g. Procam), regional climate, cultivation history, rotation history, drilling dates, fertiliser inputs, PPP inputs and nutrient history
- Contour farming, cultivating, and drilling horizontally along the slope direction of the land, producing rills that reduce flow and promote water infiltration
- Precision fertiliser and PPP application, only when capacity and demand is high.

3D farming

Agroforestry within cropping systems, including:

- Agroforestry usually consists of arable crops being grown between rows of trees planted 25-40 metres apart
- Trees create a beneficial microclimate for row crops, protecting them from wind and overheating. Deep roots mine the soil for nutrients otherwise unavailable to the crop and the leaf-litter provides a surface mulch
- To minimise competition, the tree roots and canopy should occupy a different space to the annual crop, and should use different resources of sunlight, water and nutrients in different periods of the year
- Fruit and nut trees provide an additional perennial crop grown alongside an annual rotation.





START PLANNING

MORE EFFICIENT LAND-USE: LIVESTOCK

Grazing livestock within a farming system is one of the key principles of regenerative agriculture and can contribute to farmers achieving the other 'golden rules', leading to dramatic improvements in soil-sequestered carbon and a significant increase in soil health. A diversity of grazing animals (cattle, sheep, chickens, pigs and goats) will further boost soil fertility and biodiversity.

Scientists are split on how much carbon may be sequestered using grazing animals. Some research shows as much as 8 tonnes of carbon per hectare per year may be captured under adaptive multi-paddock, or 'mob grazing' systems. This may be at the upper end of expectations, but under good management, between 1 and 3 tonnes of carbon per hectare per year should be achievable.

Adaptive multi-paddock grazing

It is essential that the grazing animals are managed correctly to maximise the beneficial impact they have on the land by:

1. Grazing plants at the correct stage in their life cycle – when they are at, or nearing, maturity i.e. starting to enter their reproductive phase
2. Grouping animals together in a tight 'mob' on a patch of land and moving them regularly to fresh grazing.



Precision grazing techniques incorporate grazing software, technology, environmental monitoring and sensors. Precision grazing can increase forage production by 30%.



Diverse swards

Grazing herbal leys which include a mixture of plant species can reduce reliance on chemicals and increase the biological activities of our soils. Livestock performance can also be improved within these systems and trials have shown animals can self-select the most nutritious diet when offered a varied platter. Additionally, some of the plants grown in an herbal ley have anthelmintic properties.

SPECIFIC BENEFITS INCLUDE:

1. **Improved livestock performance** - trials have shown animals can self-select the most nutritious diet when offered a varied platter
2. **Anthelmintic properties** of some plants within the sward - chicory or sainfoin for example - help to reduce the internal parasite burden in the grazing animal
3. **Improved drought resilience and water infiltration** can extend the grazing period by mitigating the adverse effects of weather.

Silvopasture

Silvopasture involves integrating trees within grazing landscapes – tree planting should extend beyond managing or planting shelterbelts, riparian strips and hedges. Trees provide livestock with protection from wind, sun and rain, as well as a certain amount of browsing potential (grazing of foliage) which is often very beneficial to animal health, as the browsers can access minerals that might be otherwise unavailable. The trees also give extra income, either from fruit/nut harvesting or periodic timber/wood chip harvest.



Farm of the Future report, pages 21-22





START PLANNING

ANIMAL HEALTH AND WELFARE

Improving livestock health is essential to enhancing productivity levels. Healthy animals perform better, with lower environmental impacts. If demand for meat can be met using fewer total livestock, or in less time, total maintenance costs are reduced. Resource use (feed, land, water, fertilisers and fuels) and GHG emissions decrease, both per farm and per kilo of meat. In dairy farming, there is a direct correlation between the farms with the healthiest cows and those with a lower carbon footprint per kg of milk.



Reducing GHG emissions by improving productivity and animal health is not prescriptive in terms of the systems, methods or technologies used. The focus is on meeting or exceeding benchmark values for key performance indicators (KPI), whether these relate to health, feed efficiency, growth, carcass quality, or other metrics.

Significant knowledge gaps still exist relating to the impacts of livestock health and welfare on GHG emissions. Progress will be driven through the adoption of new and emerging management practices, often with the support of innovative tools, technologies and systems.

Precision farming approaches

Precision technologies monitor animals and/or their environment to determine livestock health, wellbeing, reproductive and/or productive status of the animals. This information can inform management decisions and enable early intervention before clinical signs of illness - reducing the need for antibiotics and negative impacts on productivity. The use of technology, robotics and other automated systems also frees up skilled labour for animal husbandry.

Additionally, precision diet formulation - targeted according to the variety of nutrients required by individual animals - could confer significant benefits to animal health and productivity.



Decarbonising Intensive Meat production page 6





START PLANNING

FEED ADDITIVES

Reduction of methane emissions from both monogastric animals and ruminants through adapted feed rations and/or use of methane-reducing additives, vaccines or technologies is a rapidly evolving field. The Committee on Climate Change recommend methane inhibitors be added to ruminant diets. However, despite extensive research on developing feed additives or vaccines to target methanogenic rumen microorganisms, most are still not yet commercially available.

Improvements in GHG emissions and nitrogen efficiency can be achieved by reducing total dietary protein, while supplementing with specific amino acids. In pig farming, formulating diets to optimise both feed cost and environmental impacts can reduce GHG emissions by 9.6% per kg of bodyweight.



Feed choice may be equally, if not more, important than feed efficiency. For example, feeds which import soya from verified deforestation-free, sustainable sources can reduce indirect GHG emissions arising from imported feed ingredients.

In addition to feed additives and vaccines that can reduce methane emissions, identifying genotypes and phenotypes associated with reduced levels of GHG emissions across the entire livestock sector, combined with better understanding of the opportunities and limitations of manipulating rumen function, could offer technical decarbonisation solutions.



Decarbonising Intensive Meat production pages 10-11





START PLANNING

GENETICS

Genetics can play an important role in determining animals' susceptibility to disease and their responses to other physical, environmental and social stressors. Breeding programs to improve feed efficiency have been implemented in UK pig and poultry production for several decades, yet this KPI could be enhanced further in intensive beef cattle as, at present, as much variation exists within as between breeds.

Genetic advances in dairy enable integrated, farm-wide breeding strategies using genomics and sexed semen to drive environmental improvements on farm and develop key sustainability traits.

Two new genetic indexes help farmers breed more environmentally friendly cows.

- EnviroCow is one of the first genetic indexes in the world to focus solely on breeding cows for their environmental credentials. Incorporating cow lifespan, milk production, fertility and the new Feed Advantage index, it reflects the important role genetics and breeding play in improving the environmental efficiency of milk production
- Technology from ST Genetics has identified and mapped the genes responsible for increasing Feed Conversion Efficiency which, if adopted, could transform the reduction of dairy's carbon footprint.

Advances in genomic testing has enabled the identification of a herd's most efficient and therefore most sustainable cows to breed from. Farmers can now identify cows that produce higher levels of milk solids with the same level of input, enabling them to produce the same or more milk solids with fewer cows.



*The Decarbonising
UK Dairy
Production sector
paper page 15*





START PLANNING

ORGANIC FERTILISER TREATMENT AND APPLICATIONS

The UK Government's 25 Year Environment Plan (2018) refers specifically to soil health. A key objective is to improve soil condition and carbon storage by adding organic matter.



Organic fertilisers include livestock slurry and manure, frass (insect excrement producing chitin-rich fertiliser), digestates, composts and green manures, as well as organic bioproducts from production and waste industries.

Repeated applications of organic fertilisers over several years can create a measurable change in soil organic carbon. If managed correctly, organic fertilisers have the potential to reduce long-term reliance on synthetic fertilisers, further reducing the carbon footprint of nutrient management plans.

Precision N fertilisation using soil testing and crop sensors can improve the timing and spatial targeting of applications to meet crop requirements. Timings should also be informed by medium-range weather forecasting and soil moisture assessments to minimise risks of nitrous oxide (N₂O) losses from nitrate fertilisers and ammonia (NH₃) losses from manure and slurry applications.

Further treatment of organic fertilisers can stabilise nutrients to reduce the hazards and risks associated with application. Treatment processes can alter nutrients towards a more crop available form.

- Processing of digestate to produce ammonium sulphate fertiliser, which can be used more efficiently and improve the operational footprint of both the producer and the farmer
- Slurry acidification reduces the pH of animal slurries to between 5.0-6.0, reducing the risk of ammonia volatilisation - a cost-effective way of reducing emissions (£96 t/CO_{2e}).



Farm of the Future report, pages 33-37, 100

DID YOU KNOW....

Covering of slurry storage, anaerobic digestion of slurries, manures and residues, plus low emission spreading techniques with targeted application will reduce nitrogen and carbon losses from manure management. In addition, reducing the protein levels in cow rations will also avoid wasting nitrogen.





THINK AHEAD

1. *Smart farming*
2. *Future farm energy production*
3. *Delving deeper into farm-scale anaerobic digestion*
4. *Energy storage (ES) technology and uninterrupted power supply (UPS)*
5. *Assessing and adopting net zero fuel options*
6. *Autonomous vehicles*
7. *Automating the fruit and vegetable sector*
8. *Novel protein sources*



The 'Think ahead' section of the guide includes actions which can create a circular farming system that could sequester more carbon than is emitted. These actions are at the cutting edge of innovative farming, which means there are questions still to be answered around how best to implement the actions on-farm. Think about which of these long-term actions could complement what you already do to help futureproof your farm business.





THINK AHEAD

SMART FARMING

Policy is increasingly intervening in farm practice and financial support has shifted towards the environment. The expectation is for farmers to reduce use of inorganic fertilisers and increase soil organic matter to improve its nutrient and water retention, thereby improving its resilience to cope with climate change and reduce emissions.

Digital solutions to analyse soil health and nutrient requirements are being more widely discussed but these still come with challenges. They would need to be accessible to all farm sizes, but cost and connectivity are currently huge barriers to uptake; hence, the need for better internet coverage across rural areas.

The processing industry is also required to reduce their supply chain emissions, including Scope 3 or external emissions. This will add pressure to farmers to improve the climate credentials of their own practices to maintain their markets.

Options and requirements for smart farming:

- Adopting digital technology analysis
- Precision farming to apply any necessary pesticides and fertilisers
- Site specific targeted inputs
- Data based solutions to repetitive field tasks
- More investments into rural digital coverage.



*CASE STUDY 5:
'Map of Ag' and
Kelloggs - Smart
farming system
P34 Cereals
Decarbonising
paper*





THINK AHEAD

FUTURE FARM ENERGY PRODUCTION

Farms require heat for a range of purposes e.g. grain and vegetable drying, produce chilling, controlled livestock environments and the farmhouse. There is likely to be a 30% increase in farm electricity demand by 2050. 'Behind-the-meter' renewable energy (produced and used on-site) is therefore needed to provide farmers with cheap and sustainable electricity.

Currently 22% of farmers have selected **solar energy** as a diversification option, with farms receiving a negotiated payment per acre/hectare for the use of the land for 25-40 years. In the future, it is likely that solar energy generation will be more commonplace for the farm itself, as well as a diversification option. Emerging innovations include solar photovoltaic thermal hybrid panels (PVT) with the capacity to generate both electrical and thermal energy.



*A small **wind turbine** makes an excellent addition to a solar photovoltaic (PV) system because the wind often blows in winter when the sun doesn't shine. Both technologies are among the cheapest forms of producing low-carbon electricity.*

Other options include the introduction of **heat pumps**, especially for heating properties not on the gas grid. It is possible to use heat pumps in older buildings or to have a hybrid system which includes a liquid petroleum gas (LPG) boiler and a heat pump.

Where a suitable watercourse is available, **small hydropower projects** can also provide farms, communities and businesses with a non-intermittent supply of renewable electricity. Several have already been built by community energy initiatives, providing wider rural benefits, but on-going support is required.

Farm-scale anaerobic digestion (AD) based on livestock, local food waste and crop residues, particularly at small scale, has massive potential to provide 24/7, net zero energy production which can be used flexibly for heat, electricity and transport fuels. This can include modular systems.

For more information, visit chapter 5 of the main Farm of the Future report.



Farm of the Future report, page 53

CASE STUDY: WYKE FARM'S CARBON NEUTRAL CHEESE

Find out how Wyke Farms, the UK's largest independent cheese producer, has met all its energy needs through renewables and adjusted farming practices to enable its prize-winning 'Ivy's Reserve Vintage Cheddar' to be certified carbon neutral.



THINK AHEAD

DELVING DEEPER INTO FARM-SCALE ANAEROBIC DIGESTION

Organic materials are an essential source of nutrients and energy. Animal slurry alone has a methane potential of around 1 billion m³ or 10 billion kWh of energy per year, if this material is not digested, then the estimated GHG potential is 3 million tonnes CO_{2e}.

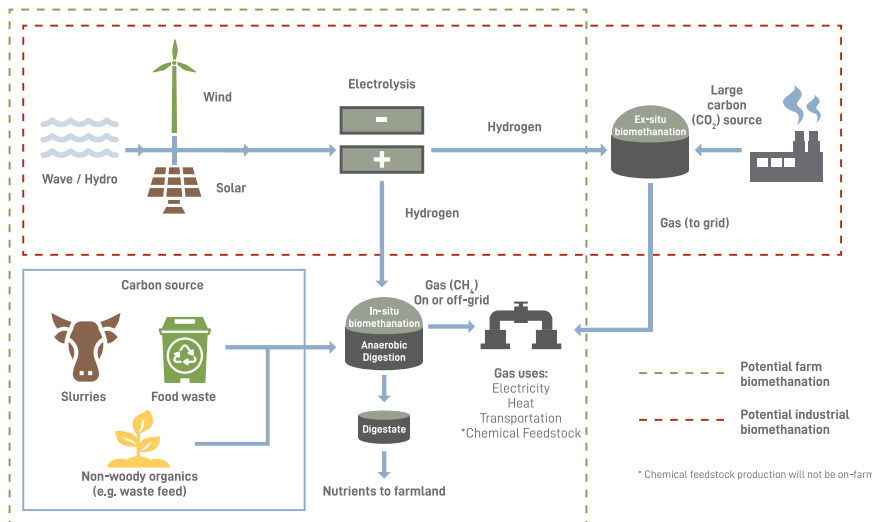


The anaerobic digestion (AD) process breaks down biodegradable materials (feedstock) in a controlled space, in the absence of oxygen to produce methane-containing biogas and digestate fertiliser - a valuable source of nutrients.

The AD process changes the characteristics of the original feedstock materials, increasing pH and converting organic nitrogen (N) to ammonium (NH₄⁺), to produce a product with more readily available N. The resulting digestate can be a great fertiliser replacement and provides improved scope for targeted N application to meet crop requirement.

Digestate contains a low organic carbon content compared to nitrogen, most of which is readily available as ammonium (C:N ratio 4:20). Quantities of phosphate, potash, sulphur and magnesium vary depending on the feedstock. Normally produced 'whole' (a slurry with 3-10% dry matter), digestate can be separated into fibre (20-40% dry matter) or liquor (1-6% dry matter).

AD is a well-established technology and modern modular farm-scale solutions are becoming commercially available. Not only should livestock farms consider on-site AD systems, but there are solutions such as covered lagoons that capture fugitive methane – but gas yields may be lower.



Farm of the Future report, pages 56-60



PRINCIPLES

ACT NOW



START PLANNING



THINK AHEAD



PROMOTING BIODIVERSITY

WHAT DOES FUTURE POLICY LOOK LIKE?

SUMMARY



THINK AHEAD

ENERGY STORAGE (ES) TECHNOLOGY AND UNINTERRUPTED POWER SUPPLY (UPS)

Energy storage (e.g. battery; pumped storage hydropower (PSH); electrolysis) is important for energy resilience. Battery energy storage (BES) has become increasingly accessible since Li-ion battery prices have fallen by more than 73% since 2010.



On-farm BES can be installed in a range of sizes so excess electricity can be stored and used at times where renewable energy supply is low, or at peak power demand, when the cost is high.

BES may increase as the UK's energy system decentralises and 'Time of Use Tariffs' become more common. Such tariffs will reward those able to reduce demand from the national grid, providing a commercial incentive to store electricity. Smart devices enable users to prioritise and automate energy use. On-farm renewable energy can be automated to provide a 'cascading' priority of uses. Some BES systems can provide uninterrupted power supply (UPS) in the event of power cuts – more frequent on isolated farms and in rural communities.

Heating (and chilling) are energy intensive processes with seasonally variable demand. Heat storage, transfer and recovery are increasingly important, particularly where intermittent renewables are involved. This is essential for high demand industries with temperature-controlled infrastructure such as greenhouses, polytunnels and poultry units. Phase change heat battery technology is also an option for both heating and cooling demand on farm sites.



More information can be found in the specialist Fuels and Transport paper





THINK AHEAD

ASSESSING AND ADOPTING NET ZERO FUEL OPTIONS

Smaller battery electric vehicles (BEVs), such as quad bikes and telehandlers are already becoming more common; however, current battery technology is not yet suitable for heavier tractors and harvesting equipment.

As diesel tractors become more expensive to run due to fuel price rises, alternative low emission drivetrains have started to appear, either as market-ready vehicles, such as those powered by biomethane, or as prototypes, powered by electricity or hydrogen. A further driver for such change will be the eventual removal of the red diesel subsidy.

With a range of gas power train options being developed, farms can become green fuel providers for their own vehicles – and there is also the potential to provide a service for rural businesses and communities.



Non-fossil gas fuels offer better potential for larger farm transport and machinery, having a higher energy density than electricity. Compressed biomethane (BioCNG) can be produced locally on farms, is affordable and can make use of existing infrastructure. It can also be upgraded and compressed on site, so that it can fuel both HGVs and gas tractors. For heavy traction, another option will be hybrid tractors that make use of more than one fuel source e.g. gas and electric.

Smaller robotic machinery platforms can operate very efficiently with renewable electricity generated on farm from solar panels, wind turbines or biogas combustion. The emergence of digitally controlled driverless (autonomous) technology and the need for more environmental and resource-sensitive field operations will lead to a revolution in vehicle design. With a move to low- or no-till agriculture, lighter, smaller automated vehicles which are more suitable for electrification could become more widespread on farms and in horticultural enterprises. This could include ‘swarm robotics’ with multiple digital, interlinked, small robots acting in tandem.



Farm of the Future report, page 62



INTEGRATING RENEWABLE TECHNOLOGIES

CNG Services is planning to construct a distributed network of AD plants in Cheshire to feed dry biogas through underground pipelines into a central upgrading hub. The digesters will be heated by ground/water source heat pumps and electricity will be supplied via a private network which includes solar generation and battery power, making the project an example of integrating renewable technologies to accelerate decarbonisation.



THINK AHEAD

AUTONOMOUS VEHICLES

Controlled Traffic Farming (CTF) is a well-established approach given a practical boost by access to reliable and affordable Global Navigation Satellite Systems (GNSS). Using GNSS, research indicates up to a 50% energy reduction with CTF, chiefly because equipment is operating on a compacted pathway and not on loose soil, minimising rolling resistance.

Other factors contributing to energy savings are:

- Less draft force required in untrafficked areas
- Less need for deep tillage to break up compaction
- Improved efficiency with well-planned field routes.

Using GNSS, the next step will be autonomous vehicles. Driverless tractors have been well trialled in the management of the 'Hands Free Hectare' at Harper Adams University, a full case study on this can be found on page 93 of the main Farm of the Future report.

This technology can also be seen in 'gantry systems', where modular attachments are fitted to motorised wide-span vehicles covering all field operations.

Using artificial intelligence (AI), robotics will be commonplace within the farm of the future. Companies such as the Small Robot Company predict that future farming will be on a 'per plant basis'. Any farm, growing any crop will be able to gather intelligence on each individual plant and act accordingly, e.g. precision weeding or spraying.

The benefits include exponentially cutting chemicals, emissions and improving biodiversity.





THINK AHEAD

AUTOMATING THE FRUIT AND VEGETABLE SECTOR

Automation and robotics are often cited as ways to avoid price inflation, increase productivity and combat labour supply shortages. Agritech reports that in Holland 11% of growers are using robots and this is only going to increase throughout Europe.

The horticulture sector in particular requires investment in novel systems to:

- Improve production and processing efficiency
- Capture and utilise data
- Encourage precision farming systems.

This also includes more innovative systems such as 'vertical farming' that can base production closer to markets.

Robotics and artificial intelligence (AI) will help growers to optimise the management of resources (water, fertilisers, chemicals and fuel). More targeted actions and crop treatments are required, as well as the ability to generate data and maps which highlight nutrient deficiencies, disease infections and pest and weed infestations.

Investing in higher-tech, automated, low-carbon greenhouses that enable better control of energy emissions will boost productivity in this sector. Automation of boilers, water and lighting systems to cut energy use will also reduce emissions from fruit and vegetable production.



Farm of the Future report, page 94, 104-106





THINK AHEAD

NOVEL PROTEIN SOURCES

The interest in novel and artificial proteins has grown as dietary trends are changing and consumers are looking for methods of production which have a limited impact on the environment.

A wide variety of protein sources are becoming increasingly available to consumers. Although many are at an early stage of innovation, some are well established.

Vegetable protein: as plant-based diets increase, the demand for nuts, seeds and pulses has grown and companies such as Hodmedod's work with British farmers to source and produce a range of pulses, seeds and grains. They are also developing the production of less well-known foods, such as Fava beans and Black Badger peas.

Cultured meat: this industry has grown over recent years as diets shift to less animal-based consumption. There will potentially be opportunities for farmers to supply raw materials for the production of cultured meat.

Insect protein: this can offer protein sources with lower environmental impacts and multiple uses for this type of product. It can be started on a small scale and there are various systems of production available. Inspiro are using black soldier fly (BSF) larvae which consume food waste to produce protein for poultry farms or fish production operations. This process could also potentially be integrated with anaerobic digestion to create energy and complete a circular economy production system.



Farm of the Future report, page 115



PROMOTING BIODIVERSITY: AN EQUILIBRIUM BETWEEN FARMING AND NATURE

Nature and farming are inevitably closely inter-related. Promoting actions to enhance natural capital and biodiversity in farming operations becomes easier when natural resources are quantified and their benefits can be realised. The concept of nature as a stakeholder provides a new aspect of the farm business, where if natural processes are more productive, there is greater benefit to the business through ecosystem services. Natural assets such as biodiversity, water quality, carbon and nutrient retention, are increasingly recognised in accounting.

De-stocking large areas of land can be done in a way that increases land-use efficiency. Intensive systems can be de-stocked to reduce environmental pressure. If the land area is completely de-stocked, it may never recover to its natural state. Yet, managed passively, the maximum sustainable output (MSO) can be maintained by drawing benefit from natural capital and efforts to increase profitability.



“

Farmers
cannot be green if
they are in the red

”





WHAT DOES FUTURE POLICY LOOK LIKE?



ENGLAND

The Environmental Land Management (ELM) schemes for farmers and landowners in England consist of three complementary schemes:



Sustainable Farming Incentive (SFI) – focuses on making agricultural activities more sustainable. Initially launched in 2022, the SFI has been extended in 2023 to include nutrient management, integrated pest management, hedgerows, arable and horticultural land, improved grassland and a low/no input grassland standard. It is anticipated that the full scheme will be rolled out in 2024.

Countryside Stewardship – the government is evolving Countryside Stewardship rather than building Local Nature Recovery as a new scheme, which was originally announced as part of the ELM schemes. Around 30 additional actions will be available to farmers by the end of 2024. Countryside Stewardship Plus will be introduced to enable neighbouring farms to be rewarded for taking coordinated actions.

Landscape Recovery – will support larger landowners or land managers wishing to make long-term and large-scale changes to land use (e.g. woodland planting, extensive peatland restoration) leading to significant environmental and climate outcomes.



WALES



In Wales, the Sustainable Farming Scheme is planned to launch in 2025. The scheme is expected to encourage Welsh farmers and land managers to farm in a way that promotes a range of environmental benefits, including carbon storage, soil improvement and water quality.

Payments will be based on the principle of ‘public money for public goods’.



SCOTLAND



Farmers in Scotland will continue to receive subsidy payment under the Basic Payment Scheme – a support policy effectively inherited from the previous Common Agricultural Policy – until 2024, after which it will present new proposals for its future subsidy framework.



NORTHERN IRELAND

Farm subsidies form part of the Northern Ireland Protocol. Payments to farmers are roughly equivalent to previous CAP payment levels.



There are several area-based schemes are currently available from Northern Ireland’s Department of Agriculture, Environment and Rural Affairs (DAERA).



IN SUMMARY....

Climate change is a global threat that affects every one of us and requires urgent action from all sectors and industries. In terms of agriculture, extreme weather such as drought and flooding will become more common and severe.

The steps that the agricultural industry can take to mitigate climate change will benefit agriculture directly, as well as having a significant global impact.

We hope this guide has provided useful information about the practical changes you can make on your farm. Now is the time to take immediate actions where possible, start planning for the near future and to think ahead to identify how your farm can aspire to net zero in the coming decades.

Please get in touch if you have any questions or comments. Feedback is most welcome.

Info@i4agri.org



Printed on responsibly sourced FSC sustainable paper