Organics Recycling & Biogas

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The magazine from REA Organics and Green Gas

How farms of the future will transition to net zero

REA ORGANICS REA GREEN GAS

Farms of the Future

In March 2022, RASE published a report 'Farm of the Future: Journey to Net Zero' to offer practical agricultural solutions for swift implementation. Angie Bywater (Environmental Biotechnology Network Co-manager, University of Southampton) and Richard Gueterbock (Director, Foodchains) take us through some of its recommendations.

What will the farm of the future look like? With a wide variety of UK farm businesses, there won't be a 'one size fits all', but it is clear that there are already many 'tools in the toolbox' available to those who wish to embrace the systems change needed to decarbonise the UK's food supply chain and help meet Net Zero targets.

RASE's Farm of the Future report describes some of these tools, using case studies and examples to show how farmers can be part of the transition to a more circular economy, deploy solutions to sequester carbon, improve soil management, protect rural land and water resources and adopt on-farm renewable energy.

In addition to the main report, there are also sector brochures on:

- Decarbonising farm vehicles and future fuels (Cenex/Jonathan Wheeler)
- Decarbonising UK cereal production (Dr Nigel Davies)
- Reducing carbon emissions in the horticulture sector (Matt Appleby, Horticulture Week)
- Increasing sustainability in the dairy supply chain (John Allen, Kite Consulting)
- Reducing GHG emissions and resource use in intensive meat production (Professor Jude Capper, Harper Adams University)

With more than 30 sector experts from academia and industry, the reports highlight the value of an investment in data, technology, dissemination and training; the need for support for the protection of biodiversity and the adoption of environmentally friendly farming systems such as regenerative agriculture, as well as the need for the industry to embrace factors like dietary trends and consumer concerns.

The report is significant as it outlines the science and technologies that exist now to reduce emissions in the agri-food supply chain, alongside efforts to boost energy and food security. Recent world events have highlighted the importance of food security and the intricate relationship between fossil fuel energy and food. With food production as their primary role, farmers need to remain profitable in order to deliver the significant investment required to reduce the sector's carbon footprint and fossil fuel reliance.

Measuring farm carbon

Farm-based emissions include methane from ruminants, loss of carbon from soils through repeated cultivation and energy use by machinery. The off-site manufacture of fertiliser, agrochemicals, farm inputs and machinery accounts for a considerable proportion of emissions and energy consumption associated with farming and land management.

For those starting a decarbonisation journey, Becky Willson of the Farm Carbon Cutting Toolkit makes a number of practical recommendations in the 'measuring carbon' section of the main report, quoting the old adage 'you can't manage what you can't measure'.

Carbon measurement can be a complex endeavour – essentially attempting to quantify a biological system impacted by climate, soil type, topography, vegetation and land management practice. Nevertheless, there are many arguments for reducing carbon emissions.

High carbon emissions tend to be linked to high resource use and/or wastage, so reducing emissions also tends to reduce costs, making the farm more efficient and potentially improving profitability. Farms are also in a unique position to be able to sequester carbon in trees, hedgerows, land margins and within the soil.

Although farms may vary considerably in their emissions, the charts below show average emissions across typical farms. Becky Willson notes that finding and consistently using the correct carbon measurement tool to track progress is important.

Primary emissions for arable farming come from fertiliser production and application; and for livestock, from the animals themselves. It might be thought that nothing could be done about these, but they certainly can be reduced through a number of measures and considerable effort is being made in livestock production science to reduce the impact of ruminants.

These include investment in livestock genetics to boost key traits such as rumen performance, feed conversion and longevity; improved husbandry and welfare practices; dietary changes/ additives to reduce emissions; and improved slurry storage and handling methods, which can include options such as covered slurry stores or anaerobic digestion.

While the science of sequestration and its practical application is still in its infancy, improved genetics, husbandry and understanding of the issues could help livestock farmers to become part of the solution.

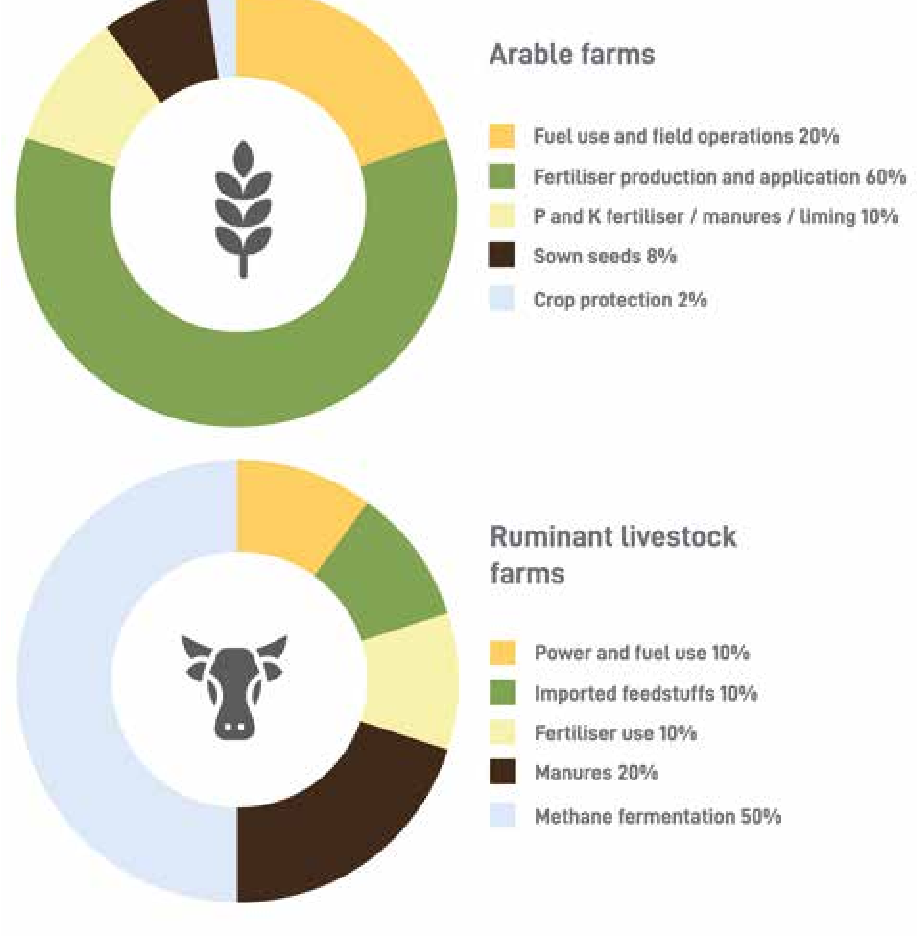
Soil management

For many decades, increasingly intensive agricultural practices have returned less carbon into the farmed soils than has been taken out. The result has been declining soil carbon (soil organic matter, SOM) leading to a corresponding decline in long-term resilience and productive potential.

Where carbon levels are suboptimal, soil degradation from compaction, wind and water erosion results in soil particulate loss into watercourses, with siltation and pollution problems from associated fertilisers and chemicals. In many cropped soils in Eastern England, soil organic matter levels are as low as 3 per cent, restricting infiltration, drought resilience, nutrient cycling and long-term productive capacity.

Soils vary enormously in their composition, but nearly all of them are improved by increasing carbon. Importantly, stable soil organic matter (hummus) can absorb six times its own weight in water, while supporting other microscopic soil dwellers that help to create a sponge-like soil structure with the capacity to absorb rainfall more effectively and help prevent flooding while mitigating the effects of drought.

Average emissions on typical farms



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Multiple approaches to land and carbon management are impacted by numerous factors, including the farm size and location, the soil types and the spectrum of management methods that the farmer wishes to adopt ranging from re-wilding to conventional systems.

Regenerative farmers such as John Cherry who co-founded the transformative farming show 'Groundswell' as a contributor, described the six key principles of regenerative agriculture:

1. **Understand the context** of the farm operation.
2. **Minimise disturbance of the soil,** both physically and chemically.
3. **Keep the soil covered**, either with living plants (green cover crop) or a mulch of crop residue like chopped straw.
4. **Maintain living roots in the soil** for as much of the year as possible.
5. **Maintain as much plant diversity as possible**, as monocultures restrict the variety of soil creatures that can be supported.
6. **Reintroduce livestock into the system**.

Regenerative farmers believe that incorporating grazing livestock into the farming system will turbo-charge the number of beneficial soil creatures. It is essential, however, that grazing animals are managed to maximise the beneficial impact on the land. Some regenerative farmers are proponents of practices such as mob grazing and the inclusion of mixed 'herbal' leys.

By-products and co-products for soil management

Although manures from grazing add valuable nutrients to soils, the application of organic materials, by-products and co-products as a valuable source of plant nutrients has long been practised. Anna Becvar of Earthcare Technical contributed a report section on the role of such products, noting that improved recovery of wastes, recycling of products, by-products and co-products to land provides an opportunity to reduce the environmental footprint of food production, as well as being part of a circular economy.

Such products include a wide variety of biodegradable wastes or feedstocks from a range of different sectors including food production, catering waste, industrial processes, water industry residues and amenity gardens. In her section on 'The potential of recycled by-products to increase carbon sequestration and encourage beneficial microbial activity in soils', Professor Jennifer Dungait of Soil Health Expert highlighted three common products:

- **Digestates**, by-products of anaerobic digestion (AD), a process which changes the characteristics of the original feedstocks, increases pH and converts organic nitrogen (N) to ammonium (NH4-N), a form with more readily available N. Digestate contains less organic carbon than compost (C:N ratio 4-20). Digestate is normally a slurry (with 3-10 per cent dry matter), but it can be separated into fibre (20-40 per cent dry matter) and liquor (1-6 per cent dry matter) fractions.
- **Composts** are used as soil conditioners due to their large organic matter content (40-60 per cent dry matter) and as a source of plant nutrients. Their nutrient value includes less readily available nitrogen compared to digestate, with losses during composting (C:N ratio >30).
- **Biochars** are produced from a range of organic materials by heating them in an oxygen-depleted atmosphere (i.e. pyrolysis). The porous carbon-rich solid (C:N ratio >30-500) is resistant to decomposition and suited to long-term storage of carbon in the soil. The physical and chemical characteristics of biochar are based on the pyrolysis conditions and feedstock. Their porous structure can hold onto nutrients in soils that otherwise have a low ability to do so.

Overall, fossil fuel-derived fertiliser use in England and Wales has decreased by around 30 per cent since 1982, with a greater reduction for phosphate and potash-based fertilisers. The effect of properly applied organic recycled by-products on soil microbial biomass, activity and diversity is generally positive. There is a direct relationship between desirable soil structure and organic carbon content that is related to an increase in microbial activity.

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The UK Government's 25-Year Environment Plan (2018) refers specifically to soil health and seeks to improve the UK's approach to soil management by 2030. A key objectives – to improve soil condition and carbon storage by adding organic matter – can be achieved whilst curbing the impacts of excess nutrients on the wider environment, including water and air

quality, and greenhouse gas emissions. Excessive application of materials to land, especially those containing large quantities of nutrients, poor timing of application, or unsuitable application techniques increase losses to the wider environment.

There are also potential benefits to using recycled inorganic by-products for soil carbon cycling. These include dust from silicate-rich rocks such as basalt, dolerite quarry fines, and industrial by-products including cement and slags from iron and steel manufacturing, which can be applied to acidic farmed soils instead of limestone to increase soil pH.

AD's role in the circular bioeconomy

In addition to the digestate fertiliser discussed above, an AD plant produces energy as biogas (approx. 55-60 per cent methane and 45-40 per cent carbon dioxide) which can be beneficially utilised for instance, in a specially designed boiler for heat-only when cows are indoors in winter, in a combined heat and power plant (CHP) to create electricity and heat, and as vehicle fuel, upgraded to biomethane and stored or used locally or directly injected into the gas grid. CHPs are usually connected to the electricity grid but can be used off-grid in 'island mode' if there is enough energy demand or storage on site.

The use of CHP has somewhat fallen out of policy favour, as the energetic efficiency of the biogas use is low, as only 27-42 per cent of the energetic value of the biogas is converted to electricity, with the bulk of the remainder produced as heat (and some losses).

However, smaller CHP plants (e.g. < 400 kW thermal) can often beneficially utilise the heat, with electricity production facilitating farm electrification: pumps, quad bikes, small loaders, farm machinery (including robotic or autonomous systems), vehicles, heating etc, as well as the introduction of on-site power or heat battery systems.

It is perfectly feasible to utilise smaller upgrading systems to produce off (gas) grid biomethane for local use in tractors and farm delivery vehicles, or in a boiler or CHP. Such systems can be used to add value to large CHP-based AD or, in smaller systems, to remove the considerable capital cost of gas injection and propane supplementation equipment.

Successive policy initiatives have largely failed to realise the numerous environmental, farming and agri-food supply chain benefits that the adoption of smaller-scale AD would entail.

The carbon dioxide (CO_2) produced from the upgrading process can also be used to offset industrial CO_2 created by fossil fuels. Such uses include greenhouse environment enrichment for improved plant growth, in abattoirs or, if upgraded to a high specification, for food and beverage industry use (e.g. beer, cola, crumpets). As a mainly pure carbon source (unlike air at 400 ppm CO_2 content), it could even be 'sequestered' (e.g. pumped underground).

Under successive UK subsidy schemes, AD plants have become larger and larger, in order to improve project economics, particularly with the cost of grid injection. The output of increased quantities of digestate requires a larger land base on which to recycle nutrients, with a commensurate increase in transport distance and cost. Crop-only digesters benefitted from a less stringent waste permitting regime, which led to their proliferation until sustainability criteria were introduced, limiting the amount of crop input in order to minimise indirect land use change.

Successive policy initiatives have largely failed to realise the numerous environmental, farming and agri-food supply chain benefits that the adoption of smaller-scale AD would entail. This has left the vast majority of slurries and manures untreated, as well as the food processing wastes produced further down the supply chain. The report identified that this is an area which needs to be addressed, possibly through carbon incentives, a clean gas floor price or a combination of grants/ low-interest loans.

Anaerobic digestion is part of the circular bioeconomy and is an important tool within the carbon cycle: it is an engineered system which captures and utilises the emissions which would naturally occur from the biodegradation of organic materials. AD is a mature and effective energy production and carbon/nutrient recycling technology, ideally suited for use in many livestock farms of the future.

The RASE will be collaborating with Harper Adams on the **Farm of the Future: Net Zero in Practice** event to be held on 13 April 2023, which will focus on technology being developed to cut farming emissions and boost resource efficiency.