A Nuffield Farming Scholarships Trust Report

Award sponsored by

NFU Mutual Charitable Trust

Charlie Steer

The Circular Farm

November 2021

NUFFIELD UK

NUFFIELD FARMING SCHOLARSHIPS TRUST (UK)

Awarding life changing Scholarships that unlock individual potential and broaden horizons through study and travel overseas, with a view to developing farming and agricultural industries.

"Leading positive change in agriculture"

“Nuffield Farming” study awards give a unique opportunity to stand back from your day-to-day occupation and to research a subject of interest to you. Academic qualifications are not essential, but you will need to persuade the Selection Committee that you have the qualities to make the best use of an opportunity that is given to only a few – approximately 20 each year.

Scholarships are open to those who work in farming, food, horticulture, rural and associated industries or are in a position to influence these industries. You must be a resident in the UK. Applicants must be aged between 22 and 45 years (the upper age limit is 45 on 31st July in the year of application). There is no requirement for academic qualifications, but applicants will already be well established in their career and demonstrate a passion for the industry they work in and be three years post tertiary education. Scholarships are not awarded to anyone in full-time education or to further research projects.

Full details of the Nuffield Farming Scholarships can be seen on the Trust’s website: www.nuffieldscholar.org. Application forms can be downloaded, but only online submission is accepted.

Closing date for completed applications is the 31st July each year.

ISBN: 978-1-912059-37-9

Published by The Nuffield Farming Scholarships Trust
Southill Farm, Staple Fitzpaine, Taunton, TA3 5SH
Tel: 01460 234012
Email: director@nuffieldscholar.org
www.nuffieldscholar.org

A Nuffield (UK) Farming Scholarships Trust Report Date of report: November 2021	*"Leading positive change in agriculture. Inspiring passion and potential in people."*

Title	The Circular Farm
Scholar	Charlie Steer
Sponsor	NFU Mutual Charitable Trust
Objectives of Study Tour	• To explore the feasibility of a circular farming system and how this aligns with the wider circular economy. • To eliminate waste and losses from the farming system. • To reduce or remove inputs to the farming system through innovation in improved nutrient cycling and energy generation.
Countries Visited	Canada, USA, Ireland, UK, Denmark, and due to covid virtual interaction with Netherlands, Finland, Norway and Australia
Messages	• The development of the Circular Economy and the Circular Farm present agriculture with a winning solution to help address the overshooting of planetary boundaries. • Climate change and the impact of nitrogen and phosphorous use require significant and swift action, within the backdrop of feeding a growing population. The principles of the circular economy - designing out waste and pollution, keeping products and materials in use and regenerating natural systems in an agricultural landscape - creates a framework for farmers to adopt circular systems. • The carbon footprint of food production is firmly on the map. Renewable energy only offers half the solution. The remainder must come from adopting a system-thinking approach to take into consideration the whole 'foodscape'. The circular economy can link the consumer, supplier, and farmer together in a self-supporting network. • We must now embrace complexity; zoom out from individual products we produce and look at how the entire system works. Careful management of the interrelationships between each part will enable farms to become a foundation for future prosperity and sustainability.

EXECUTIVE SUMMARY

The project aims to demonstrate to farmers and land managers how the principles of the Circular Economy can be adapted to create the Circular Farm. The business and environmental benefits of this approach can help reduce input costs, provide a plentiful supply of energy, improve the soil producing healthy nutritious food whilst protecting and enhancing biodiversity.

The foundation of the Circular Economy is the belief that there is no such thing as waste – this is represented by the Three ‘R’s’ of Reduce, Reuse and Recycle. This concept could become a vital part of modern food production helping to transform our systems of farming and food production to eliminate waste, better circulate resources and regenerate the natural world.

Fundamentally the soil is the centre of this transition to circular farming. A functioning and well managed soil allow efficient production of healthier, nutrient-dense food. Focus on the building of humus brings with it the retention of water, increased nutrient holding capacity, whilst sequestering carbon. Humus building dovetails into the use of bulky organic residual products forming further closed loops systems from bio-solids to vermicompost.

Examples of innovative agricultural, biological, and engineering projects in Canada, the USA, Ireland, and Holland are described in detail demonstrating methods of circular farming and the systems supporting circular food production with the objective of inspiring the wider acquisition of knowledge in this area and adoption of these and similar technologies and techniques on UK farms and elsewhere.

The project encourages farmers to adopt a designed systems approach. This involves thinking circular, rather than linear, to embrace complexity and diversity, as well as being alert to opportunities, to collaborate with fellow farmers and build relationships with business involved in food and energy production. Knowledge exchange is an important part of building success for these multifaceted interconnected systems.

The project also calls on policy makers to emulate the Dutch policy of adopting a zero-waste strategy in conjunction with climate change adaption and mitigation. One way of achieving this is to support the farming community in a holistic way to adopt Circular Farming through financial support and the removal of barriers to innovative solutions. The strategy must be aligned with producing safe, healthy nutritious food to feed an increasing global population and not by regulating activities to reduce production quantities.

Finally, the report makes the connection between the development of circular farming systems and profitable, strong and sustainable business with low risk, diverse income streams.

Contents

DISCLAIMER

The opinions expressed in this report are my own and not necessarily those of the Nuffield Farming Scholarships Trust, or of my sponsor, or of any other sponsoring body.

Please note that the content of this report is up to date and believed to be correct as at the date shown on the front cover.

CONTACT DETAILS

Charles Steer
Grosvenor Farms
Aldford Hall
Chester
CH3 6HJ

TEL 01244 670160

E MAIL: Charles.Steer@Grosvenor.com

Nuffield Farming Scholars are available to speak to NFU Branches, Agricultural Discussion Groups and similar organisations.

Published by The Nuffield Farming Scholarships Trust
Southill Farmhouse, Staple Fitzpaine, Taunton TA3 5SH
Tel: 01460 234012
email: director@nuffieldscholar.org
www.nuffieldscholar.or

Forward

The foundation of the Circular Economy is the belief that there is no such thing as waste. This is encompassed by the Three 'R's' - Reduce, Reuse and Recycle. This concept is increasingly a vital part of modern food production to help transform our systems to eliminate waste, better circulate resources and regenerate the natural world.

Waste is something I have always strived to eliminate. At school, my nickname was Stig after Clive Allen's book 'Stig of the Dump,' after I was caught pulling a lawn mower from a skip! I was brought up on an organic family farm in East Cheshire, which my parents ran alongside their professional careers. The farm was very much a family affair, and this sparked in me a passion for agriculture, wildlife conservation and sustainability. This is neatly contained in the Soil Association's circular logo.

Upon leaving school and working on farms whilst travelling through Australia and New Zealand, I read for a degree in agriculture at The University of Reading. I joined Grosvenor in 2011 on a Graduate Training Scheme and am now the Arable Manager for Grosvenor Farms Ltd, a mixed dairy and arable farm on the Welsh border, south of Chester.

Aerial photo of Lea Manor Farm, Grosvenor Farms 2020 *(author's own)*

My interest in the Circular Farm has not been a lightbulb moment but a process of evolution. The construction of the brand-new Lea Manor Dairy Unit at Grosvenor Farms in 2014 included the installation of a manure separation system. It became apparent that the 'waste' from the dairy was a valuable resource to the arable enterprise, by providing nutrients for the growing of forage to feed the livestock. The farming team experimented with manure application techniques and technology to make use of the growing quantity of fertiliser at our disposal. This example of the integration between the livestock and arable enterprises has developed into a key strength of Grosvenor Farms. I have been thus encouraged to undertake research into how the farm can be improved to become more sustainable and become a leading example of a modern Circular Farm.

The farming community are well placed to embrace the concepts of the Circular Economy. I hope examples of ingenious and creative individuals and businesses that I have investigated with the support of the Nuffield Scholarship will provide inspiration for farmers and land managers, allowing them to grasp the business opportunities a circular economy creates. The adaption of the Circular Farming approach on a wider scale could also improve national economic and environmental sustainability with simultaneous regeneration of biodiversity on farmland.

Objectives

Investigate how the use of the principles of the Circular Economy are incorporated into farming and food production systems.

Promote the concept of the Circular Farm to communities involved in farming, land management and food production.

Put into practice ideas and innovations gathered, in the management of Grosvenor Farms and demonstrate the practicalities to other farmers and interested parties.

Chapter 1: The Circular Farm

The Circular Economy

The circular economy is shaped by three principals[1]:

1. **Design out waste and pollution.** Most of the waste is created at the design stage of both products and systems: change the mindset to view waste as a design flaw, or as a raw ingredient for another process.
2. **Keep products and materials in use.** The waste of resources cannot continue: millions of tonnes of materials, from plastic to potash, are disposed of or lost every year into ecosystems, the atmosphere or water. Agriculture has been historically good at keeping some things in use by remanufacturing, reusing, and repurposing; something a low margin business must be good at. Conversely, vast quantities of nutrients and greenhouse gases have been permanently lost into the environment where they cause irreversible damage including climate change and the dead zone in the Gulf of Mexico (where algae blooms deplete oxygen from the water).
3. **Regenerate natural systems.** Nature does not heed the concept of waste; the classic example is a tree falling in the forest, decomposing by a perfectly orchestrated process to become nutrients for further growth. By first observing, then using or mimicking natural systems, natural resources can be enhanced. This concept is as old as agriculture itself using organic manures, rotational diversity and fertility building crops and has been practised the world over for thousands of years.

The Circular Farm

The above principles are used in the development of the Circular Farm. They focus on good yields, the sparing use of resources and energy, whilst putting as little pressure on the environment, nature, and climate as possible. The minimisation of inputs, be that in manufactured or mined fertilisers, pesticides, concentrated feed, energy, or time are key factors in the design of the Circular Farm. Keeping the residuals of farming, such as manure, other biomass and food processing within the farm as a renewable resource is also a crucial part of the closed cycle. The more local the loop, the more effect the systems in place.

The concept of the circular farm is as old as farming itself, not only in terms of nutrient cycling but all materials - we all know farmers that refuse to throw anything away, with the hope that 'it might come in useful one day!'

[1] The Ellen MacArthur Foundation https://ellenmacarthurfoundation.org

Chapter 2: No Such Thing as Waste

“Waste is only a resource in the wrong place” [2]

Cheap food in the West is ‘easy come easy go’: there is little incentive for the farmer, processor, or consumer to use every morsel. The scale of global food waste was put in perspective by the talk given by Professor Frank Mithlomer at the 2019 Nuffield scholars CSC in Iowa.

Frank’s presentation included the following picture from the National Geographic magazine. The picture demonstrates the quantity of food wasted by the average US family. On a global scale, food waste is cited as a third of all food produced. The United Nations Food and Agriculture Organisation (FOA) commented that if “Food Waste” were a country it would be the world’s third largest emitter of carbon dioxide after China and the US.

If food waste is now a given and the societal changes required to eliminate it are embedded in modern life, it represents an opportunity for agriculture within the circular economy. Food waste can be intercepted at each stage of the food lifecycle in agricultural production, post-harvest handling and storage, processing, distribution, consumption, end of life. Where there is a lot of waste, there is a big opportunity for the innovative circular farmer.

Two Canadian visits directly addressed the opportunity created by food waste.

The Ross family and Elmira Biogas plant

Bio-EnPower Inc. Elmira was commissioned in 2014 as the first waste to bio-energy anaerobic digester (AD) plant in Canada, an expansion in 2018 took the plant to 3MW electrical and 1.6MW thermal energy, taking in c. 70,000T of ‘source separated organics’ (akin to UK brown bin food waste collections) grease, expired food, and leftovers. The plant generates enough power for 2,800 homes and is estimated to have saved the release of quarter of a million tonnes of carbon dioxide equivalents at the time of visiting in 2020.

The plant contains patented de-packaging technology to remove 25% (and more) of inorganic plastics and metals from waste before entering the AD process, allowing a wide range of feedstock to be used. The intake area to the digester is fully enclosed and a three-step process ensures no odour escapes from the intake area. The facility produces digestate pasteurised to Canadian Federal

[2] *Mahatma Gandhi*

regulation and organic farming approval in Canada and Buck Ross, farmer and owner, described how demand was out-stripping supply for the digestate. Bio-EnPower had completed various crop trials on their farm with some impressive results.

During a fascinating tour of the impressive site, Buck explained how he had installed the most expensive toilet in Canada, a staggering $160,000. Due to 'red tape' the lavatory on site could not be fed into the digester, into which tens of thousands of tonnes of organic waste were processed. Instead they had to install a separate septic system, which baffled Buck, with the AD being located just yards away! This raised an interesting discussion on regulation hampering the progress of the bioeconomy. If there is to be transition towards the development of renewable energy from organic waste there must be a regulatory environment that allows innovation and safety without the millstone of bureaucratic rules, and the additional capital that must be employed to comply with excessive red tape making some projects financially unviable.

Buck's digester is not in isolation and anaerobic digestion the world over is proving an essential player in the circular economy. In the UK, AD offers farmers, waste processers, councils, and a combination of all parties the opportunity to unlock green energy in forms already usable by existing technology. For example, bio-methane powered transport has been recently adopted by fleet operators in the UK including Home Bargains and Amazon. The scope for AD now includes green gas injected into gas grids, supported by the green gas support scheme which has succeeded the renewable heat incentive (RHI). Currently there is no UK government subsidy for co-generated electricity and heat energy via a combined heat and power system (CHP) - but in certain situations and with power prices and demand increasing, AD's running CHP may be viable without subsidy. In addition to energy, digestate in its raw form has benefits as a bio-fertiliser and opportunities for further processing, covered later in the report, could be a game changer.

AD is of particular interest as it has symbiosis with not only organic waste from the human population but also with efficient intensive animal production systems where manures as feedstock can be captured consistently.

Enterra

Food waste can provide the feedstock for another interesting addition to the bioeconomy - insect agriculture, aka fly farming.

Enterra began in 2007 with the aim of solving two global problems: the need for finding new, sustainable sources of protein for animal feed and addressing the high prevalence of food waste.

The Enterra team's solution to these problems came in the form of a beneficial, non-invasive insect species called the Black Soldier Fly (BSF) and by developing techniques to replicate the natural BSF lifecycle. Unlike AD, where the feedstock was both pre- and post-consumer, Enterra use only pre-consumer waste food to feed the fly larvae. This recycled food is collected from local farms, grocery stores and food production facilities and contains a mix of fruits, vegetables, and grains.

The BSF larvae grow rapidly under controlled conditions, efficiently converting the nutrients in the recycled food into protein and fat. The larvae are then dried and processed into three products:

- EnterraGrubs™ – a feed supplement for poultry, wild birds, and other insectivorous animals.

- EnterraProtein™– made from de-fatted larvae. This it is an excellent source of digestible protein and can be easily blended into commercial feed pellets for fish, poultry and pets.
- EnterraOil™ – the fat component extracted from the larvae can also be blended into feed pellets or used as a pellet coating for enhanced flavouring.

The manure from the larvae is also collected and EnterraFrass™ is a fertiliser made from the "frass" (manure) of the Black Soldier Fly larvae.

To convert food waste into the products listed above, Enterra's flies consume 130 tonnes of Alberta's food waste each day. This is de-packaged, if required, then blended into a smoothie which is fed into a vertical farming system on just four acres in an industrial area on the outskirts of the city.

Buck's AD and Enterra both provide a solution that adds value to waste streams otherwise destined for landfill. The interesting part of the operations is that co-locating the fly farm, which requires energy as an input, with AD could provide a neat, and very circular set of food waste processing options. Food can be sorted into pre- and post-consumer: pre-consumer destined for the fly farm operation, post-consumer to the AD processor. Energy from the AD, both electrical and heat can be diverted into the fly farming operation, the cycle can be added to, and the value-added increased.

Lystek

Lystek's slogan is the first thing that grabs your attention:

'Nothing wasted. Everything to gain' summed up not only their business but the principals of the circular economy. The Lystek facility at Dundalk in Ontario takes in sewage and, in a single vessel, a process of maceration, low temperature hydrolysis and alkaline injection remove all the pathogens allowing a fertiliser product "LysteGro" to be produced and marketed to farmers in the vicinity. The process itself is unique and can fit into systems using AD as well as more conventional sewage treatment facilities. Adding the Lystek THP (thermal hydrolysis process) into an AD system not only pasteurises but also breaks up long chain hydrocarbons presenting more available carbon into the AD process for digestion into methane.

Lystek provides a service to farmers and conducts field trials to evaluate LysteGro (liquid fertiliser) and promote its benefits. The company has an impressive fleet of equipment to distribute and accurately apply LysteGro and provides spreading via contractors or 'custom' operators as part of the service. The tanker set up which Sam Halloran, Product Manager with Lystek, took me to see makes most UK kit look like toy tractors. The operation was very slick to keep farmers supplied, and allowed timely application for agronomic and environmental benefits.

With a good hour spent sat with the operator, I was given a real insight into the operation, as 40,000 litre tankers were quickly emptied and injected into the field at a rate of 2,800 gallon per acre (31.5 cubic meter per ha). The application method is a cultivator injector, allowing incorporation of the product, which is a legal requirement, and a cultivation pass, removing what little compaction the 60-ish tonne setup placed over its four axles. Application rates were mapped using a Trimble GPS system and applied at rates depending on crop requirement and soil sampling results. The data was shared with the farmer for record keeping and subsequent management decisions.

"Right time, right place, right amount"

Ostara Nutrient Recovery

Another company in Canada pioneering the concept of a circular system is Ostara Nutrient Recovery Technologies, which was born out of innovation first researched at the University of British Colombia. The technology is now in fifteen sewage works in Canada, the US and Europe. The system fits into the effluent out-flow of sewage works, where chemical flocculants would have been applied, to remove phosphorus and convert it into a saleable, slow-release fertiliser.

The background on global phosphorus puts Ostara's process into context. Phosphorus and nitrogen are essential for human life as some of the elements crucial for the structure of DNA. Use of phosphorus and nitrogen is one of the planetary boundaries that is currently being overshot, massively. The well-publicised hypoxic 'dead zones' in the Gulf of Mexico are partly due to phosphate leaving agriculture, industry and water treatment in suspension and dissolved in water washing out of the Mississippi river. The phosphate in the water, along with other nutrients, causes eutrophication creating a perfect environment for single celled organisms to thrive. These organisms rapidly multiply and consume the oxygen in the water required for other organisms. Aquatic life then dies and their decay results in more nutrients, feeding more algae and bacteria and a vicious cycle starts to affect vast areas of coastline habitat where countless aquatic species had once thrived. The ecological damage caused by these dead zones is only part of the problem as humans are also able to transport phosphorus across the planet, concentrating it in areas of higher agricultural productivity, where it is then either lost from the food system through production or, after passing through humans or animals, into water. Phosphorus from readily available sources is expected to reach its peak by 2030, thereafter extraction will become drastically more expensive.

Ostara have identified the market in global phosphorus and, by capturing it at areas of incredibly high loading at sewage works, are capitalising on the opportunity.

The technology is a 'fluid bed crystallisation reactor.' This is a vessel where the growth of struvite (magnesium ammonium phosphate) is promoted. To do this magnesium is added to the incoming waste stream in an environment that encourages the rapid crystallisation of struvite. The crystals grow and sink down through the vessel where they are extracted and dried into a fertiliser called Crystal Green.

Crystal Green contains 5% nitrogen, 28% phosphorus, 0% Potassium and 10% magnesium. This formulation is unique as it is insoluble under normal conditions, unlike most rock phosphate sourced fertilisers. The sustainability credentials of the product continue to impress when this is considered. Instead of leaching, Crystal Green is acid soluble, the fertiliser responds to root exudates of weak acids such as citric acid. This dissolves the fertiliser and allows plant uptake. This response to plant growth is in balance with the requirements of the plant. As growth stops at harvest for example, root exudates stop and so does the phosphate release from Crystal Green. The slow and plant promoted release of the phosphate is not only better matched to crop requirement, but leaching is exceptionally low. Ostara are not only capturing phosphate but preventing losses from the food system and perfectly demonstrating a win-win by whole heartedly embracing the concepts of the circular economy.

Over the past 50 or so years the specialisation of agriculture has seen livestock farmers concentrating in areas where the factors for profitable production are favourable. Sitting in one of the most densely populated parts of the UK for dairy farming in Cheshire explains why; the climatic conditions, distance to markets (population), expertise, supporting business such as processors, vets and contracting operations means that clusters of intensive and efficient farms using various production systems develop and expand. This results in a strain on resources and in particular overloading of nutrients on the environment. Recent changes to the farming rules for water in the UK, coupled with the Clean Air consultation in 2018, will see regulation squeezing margins by requiring compliance, management changes and capital investment. Across the world the story is familiar, from counties in the UK, states in the USA such as Wisconsin and California to whole countries, New Zealand, and Ireland. All facing similar challenges. The focus on nutrient recovery in the livestock sector was a fascinating insight into the opportunity from manure.

"Where there's muck there's brass"

Robinsway Dairy & Bucky Bloom

Livestock water recycling (LWR) does exactly what it says on the tin. Their system uses three steps to separate slurries or digestate into products that can be used back in the farming system, creating the ever-desirable closed loop system.

Not dissimilar to separation systems, commonplace in the UK, the initial step is to remove most of the large, solid particles through a roller screen separator. The solid stream is then a stackable, easy to spread source of organic matter. This solid contains most of the carbon, so is well suited to anaerobic digestion or composting operations. The liquid from the initial separation system then goes through the LWR process. A flocculant polymer is first added to the incoming liquid and agitated. This then causes the solid material left in the manure to stick together which can then be mechanically skimmed off and added to the larger fibre from the initial screening. The next steps involve filtration of the waste stream and finally reverse osmosis to purify the water, simultaneously concentrating the nutrient in the waste stream. This results in three products, 75% clean re-usable water, 17% concentrated liquid nutrients and 8% solids. In areas where water availability is scarce, regulated closely or expensive the water is a valuable resource as a nutrient containing products.

At Robinsway Dairy in Wisconsin, the water is used to wash sand from a sand bedding recycling system in addition creating a closed loop for bedding within the farming operation, for flush and wash in the dairy and through centre pivot irrigators. The nutrient containing liquid is significantly reduced in volume easing pressure on farm storage infrastructure. The consistency of the nutrient rich product at a high concentration makes application of the 17% nutrient dense liquid portion as simple as applying a manufactured liquid fertiliser. The consistency of the product has opened doors for the Binversie family who now market the solid and liquid materials as a natural 'organic' fertiliser for the home gardener, labelled as Bucky Bloom (www.buckorganics.com). They also use it as a fertiliser on the farm in a conventional manner.

BioFiltro

BioFiltro is a wastewater treatment company who have applied their worm powered process in full scale at Austin Allred's Royal Dairy in Washington. Prior issues, some of them resulting in costly legal fees, meant that pumping slurry into the irrigation systems was no longer an option. Trucking slurry to off-lying land also had become environmentally and financially unsustainable. Alongside Austin, the team at BioFiltro have addressed this challenge by installing a six-acre worm bed. This uses large shallow tanks, recycled plastic pallets, a layer of river cobbles then a couple of feet of low-quality wood chip which is a by-product of clearing fire breaks. The chip is then inoculated with worms, microbes and specific bacteria and fitted with surface irrigation system.

Austin's dairy uses a flood or 'flume' wash system to clean passageways. The flume wash water like LWR, goes through a roller press separator to remove the course fibre. The solids again go to a composting process or are land spread. The liquid is pumped over the worm bed, telematic systems carefully monitor the performance, inflows, and outflows of the worm bed or 'BIDA' (**Bi**o**d**ynamic **A**erobic) system.

Liquid from the flume wash being pumped onto the Biofiltro BIDA at Royal Dairy.

The magic starts when the worms, bacteria and the woodchip combine to capture 90% of the incoming phosphorus, nitrogen, and suspended solids. Worm castings are then harvested from the system as a valuable vermicompost once every 12-18 months, after which the remaining woodchip and worms are screened out and returned with the addition of fresh woodchip to the BIDA. The treated water coming from the system can then be pumped back to be used for flume washing the passageways again and, when in surplus, through irrigation pivots saving the financial and environmental cost of trucking and further irrigation water abstraction. The reduction in waste goes further as BioFiltro have ambitions to make their system from concrete Lego blocks so they can be readily expanded or reused.

The benefits to Austin's dairy are numerous. Firstly, the costly transportation of the manures to outlying blocks of land has stopped. Secondly there is a huge reduction in the volume of abstracted water, with the added benefit that the treated water, although not clean enough to discharge, has no smell, and increased beneficial microbial activity. This stimulates soil life during irrigation. Thirdly the worm castings generate revenue, once removed from the BIDA, it is retailed to a third party: Russ Davis's company Orgainx (www.organix.us) is a composting operation which, after screening the casings, distributes the product under the brand "Kasting King". Russ is also distributing the liquid as "VerMedix" marketed *as "a soil amendment to rebuild and enhance low and moderate producing soils. Containing billions of beneficial microbes per bottle."* Austin and Russ are investigating markets for the surplus worms from the system. Finally, and by no means, least the methane reduction from the system is applicable in the US for a carbon crediting scheme, worth 88USD/cow to a system on the scale of Royal Dairy size. The eight ton per cow carbon dioxide equivalent credits are calculated as the BIDA is treating the manure removing methane emissions from the standard practise of lagoon storage.

The author, Austin Allred (Royal Dairy) and Matias Sjogren (Biofiltro)

Austin and his family have a high profile in US dairy and he has quickly become the face of sustainable, high output dairying, partly due to the manure treatment through the BioFiltro system.

Austin describes the benefits of vermicompost by simply saying *"whatever comes out the back of a worm is perfect for plants."* Regenerative farming guru Graeme Sait on his Nutrition Farming course extols the virtues of supporting earthworms in any farming system. Graeme states the worms' guts not only contain unique organisms, but the castings they produce contain seven times more phosphorus, ten times more potassium, five time more nitrogen, three times more magnesium and one and a half times more calcium than the surrounding soil. The calculation follows on from the rule of thumb that if a shovelful of soil contains twenty-five earthworms, they would be producing a staggering three hundred tons of castings per hectare.

BioFiltro impressed me with its simple design, use of readily available materials and Matias's enthusiasm for worm power. BioFiltro has systems running from the Antarctic to the deserts of Chile, treating waste from abattoirs, vineyards and even a chain of roadside service stations. The principals of the circular economy are adopted and align with the three principals of the circular economy. The BIDA is made of recycled materials and using the 'Lego block' system Matias mentioned would mean a fully reusable design. Furthermore, it uses waste from fire break clearance or low-grade woodchip as the substrate for the worms. The system keeps products, namely water and nutrients in use and adds value through retailing these (although this might be exporting valuable nutrients from the farming system). BioFiltro use the words "a wastewater solution regenerative by nature restorative by design" in its marketing material a perfect fit with the third principal of regenerating natural systems.

Project Slyri

In 2017 ColegSirGâr at Gelli Aur College in Carmarthenshire launched its ambitious project to reduce diffuse pollution from slurries starting at the college's 600-cow dairy unit. At the core of the project is water quality protection. In conjunction with Power & Water (UK-based water treatment technology company) they have developed a farm-scale slurry treatment process to reduce the storage volume of the slurry by 80% in turn increasing nutrient content and reducing volume to spread.

Slurry from the college's 600-cow, part grazed, part housed dairy is pumped into a conventional slurry store. From here three treatment processes are used.

1. *Solids Separation:* Two separation systems were in place undergoing trials at the time of visiting. The more successful, but power hungry, of the two is a decanter centrifuge system removing 52% of the solids. Decanter centrifuges use centrifugal force (spinning around a horizontal axis) to spin solids from liquids. Solid laden liquid is pumped down the centre of a centrifuge 'bowl' a tube and spun to produce G-force. The spinning throws the solids away from the liquid through an orifice, where a screw conveyor removes the solid material. This solids removal at the front end of the system is critical to the flowing stages. Consistent dry matter and total suspended solids are key to the reliability of the system. Changing dry matters due to bedding, feed and rainfall onto yards were giving John Owen, Neil Nicholas, and the team at Gelli Aur College the biggest headaches.
2. *Flocculation and DAF:* The next stage is flocculation of suspended solid material via "Soneco," a patented electrode-based system for flocculation designed by Power & Water. This uses a consumable aluminium anode, creating positively charged aluminium ions that electrostatically bond to suspended solids, these precipitates the solids out of the solution and float to the surface where a series of paddle like flights on a driven chain skim the floating particles into a disk stack separator, where the flocculated cake is stacked with the solids from stage 1. The liquid passes to stage 3.
3. *Disk Stack Centrifuge:* A Disk stack centrifuge again uses centrifugal force over a large surface area to spin solids out of liquids. The difference between a decanter and disk stack is the latter spins about a vertical axis. G-force spins the solid particles, from 0.1 to 150 microns down the stacked separator conical disks. The particles spin to the edge of the separator 'bowl' where they are continuously removed. Varying the speed of spinning disks varies the level of separation. In common with all centrifuges, there is a large power demand: a key requirement to make a fully closed loop, is generating enough power on farm to run such equipment with a high-power demand.
4. *Advanced oxidation process (AOP*): Uses oxidation reactions to remove any pathogens remaining in the slurry via hydroxyl free radicals. These are produced in another Soneco rector and can reduce the chemical oxidation demand and total organic carbon of the water down to levels suitable for discharge to the watercourse, or reuse on the farm.

The “Soneco” electrode, marked DB2 on the front of the AOP “Advanced Oxidation Process” tank.

The system is a proof-of-concept trial with capital from the Welsh Government’s ‘Rural Communities Rural Development Programme 2014-2020’, which is funded by the European Agricultural Fund for rural Development and the Welsh Government. The system had, as to be expected during innovation, been modified: for example a larger DAF tank was running in parallel to the original, and, as to be expected, is constantly evolving. The concept is excellent and provides some clear benefits to enable nutrient cycling and water reuse. Environmentally it reduces slurry storage volumes, allowing targeted application in favourable weather and soil conditions and at the correct time for crop nutrient uptake, reduced water abstraction due to the ability to re-use the treated water. Financially the reduction in volume equates to lower capital for storage infrastructure, lower operating costs for spreading and the displacement of manufactured fertilisers through efficient use of manures. There would have to be careful analysis of the running costs and capital outlay for the system, it would also require farmer training and supervision to run the system proficiently. If on-farm renewable electricity could be used, the process’s ability to circulate and retain nutrients on the farm would have a significant impact on the carbon footprint of production. This is enhanced by the savings associated with effective use of organic manures as fertilisers over products made or mined.

CCm Technologies

Fertiliser production and application is a large source of greenhouse gas emissions in agriculture. The Intergovernmental Panel on Climate Change (IPPC) has estimated that 6% of the emissions from agriculture are from nitrous oxide (N_20) and about three-quarters of those N_20 emissions come from fertiliser. In some cases, 7,000kg of CO2-e (carbon dioxide equivalent) are emitted in the production of 1,000kg of ammonia nitrate fertiliser. *(Source: International Fertiliser Society: The Carbon Footprint of Fertiliser Production: Regional Reference Values)*

There is huge scope for reductions in greenhouse gas emissions, as well as soil and water improvement by adopting circular techniques for the processing and application of 'bio fertilisers.'

In very simple terms the benefits are three-fold:

1. Collection, processing, and use of organic waste results in reduced methane emissions, especially when used as feedstock for anaerobic digestion.
2. Reduced emissions from the production of fertiliser. Fertiliser production from the Haber-Bosch process, which converts hydrogen and nitrogen to ammonia, relies on natural gas and high temperature. Rock-derived fertilisers require mining and processing. There is scope to decarbonise the production of ammonia using hydrogen, but this is not presently an option.
3. Reduced emissions in application. Urea, the most widely used fertiliser globally, releases carbon dioxide on application. Urea also releases nitrogen oxides (a greenhouse gas 210 time more potent than carbon dioxide) during the nitrification process in the soil.

In addition to the greenhouse gas (GHG) savings, the processing of bio fertilisers addresses the issues of concentration of nutrient rich waste in certain areas. Creation of a bio fertiliser allows the efficient re-distribution of nutrient from areas of surplus to areas of deficit.

CCm Technologies is a UK based clean tech company producing a climate positive fertiliser from organic waste streams. Chief executive Pawel Kisielewski and chief technical officer Peter Hammond explained how the process works.

1. *Organic waste input:* High dry matter homologous organic waste, over 25% dry matter, is ideal feedstock for the process. Separated solids from slurry or digestate separation is a good starting point.
2. *Weighing and Blending:* The organic waste material is weighed out and blended with additional inputs depending on the customer specification. This could be a manufactured input eg, DAP or another dry input.
3. *Carbon dioxide capture:* CCm Technologies rely on the incorporation of carbon dioxide into the product, anhydrous ammonia is reacted with compressed carbon dioxide in a mixing vessel creating a nitrogen rich carbonate paste. This is pumped into a further mixing vessel where the organic waste stream and the carbonate paste are combined. Once mixed the product is pelletized in a pellet mill, identical to that found in feed mills to create a carbon neutral dry pelletised fertiliser.

When thinking of a fertiliser plant most people think big industry, e.g., Yara's 135 ha site in the Netherlands or the 50ha site at Ince on the Dee Estuary. CCm Technologies offer a different solution, the plant design is a modular 10,000 ton per annum units that are not dissimilar to a grain drier in appearance and operation. The picture below shows the prototype plant in Swindon.

They can use any form of organic waste, be it compost, digestate, food residues, sewage sludge or chicken litter. Enabling decentralised fertiliser production has additional benefits to support the circular economy. Wastes can be processed at the production site and distributed into agriculture locally, saving on transport. Conversely, the fertiliser can be produced at an area of high nutrient loading, in areas of high livestock or human population density and shipped economically to areas requiring additional nutrient.

A couple of factors in recent months have changed the landscape for on-farm fertiliser production.

Firstly, the 2021 changes to farming rules for water significantly reduced the scope for autumn application of organic manures to minimise nutrient loss over the winter. The possibility of producing a dried fertiliser for application in the spring from products such as digestate and sewage sludge has now become an option forced by regulation.

The second factor is the shift in global energy pricing, especially in the UK. This shift in the price of raw materials has seen the only manufacturers of ammonia nitrate in the UK shut down their operation. The effect of this is a tripling in the price of nitrogen fertilisers. High energy costs also push up the costs of mined inputs. These two factors alone will bolster the development of the biofertiliser industry, in a drive to ensure an economic and secure fertiliser supply. The development of biofertiliser will bring a circular solution to plant nutrition, with a far lower environmental footprint than the fossil fuel alterative.

Lessons learnt from waste recycling, recovery and reuse case studies and the implications for the Circular Farm

Discussing the opportunities for the Circular Farm with the innovators in the waste and nutrient recovery and anaerobic digestion industries gave an exciting insight into the possibilities for circular products highlighting additional revenue generation from wastes.

The businesses visited had one thing in common, vast amounts of capital requirements. From $17 million AD plants to biofertiliser plants starting at £2 million. High capital means that the creation of circular farming systems using the solutions seen is not within easy reach for most farming enterprises.

A way that capital for such schemes could be more easily in reach of farming business in the UK is the formation of farmer and industry cluster groups to provide bio energy and bio fertiliser for their own use and local demand.

Chapter 3: The Circular Farm – creating and capitalising on systems

The previous chapter gave an insight into the possibilities different technologies give as moving parts in the farming system. To capitalise on circular systems, the ability to identify all the interconnections on the farm is key. Management by design is most important. Adoption of this 'Systems Thinking' is key - it is always better to manage by design than default.

The following case studies demonstrate the possibilities for farming business when systems thinking is employed, and dynamic complexity is embraced.

Fair Oaks Farm

Fair Oaks in Indiana is a remarkable setup. The beating heart of Mike and Sue McCloskey, Fair Oaks is a 38,000-cow dairy business, apart from the scale, the business is truly multifaceted. Two aspects worth mentioning, firstly the public-facing nature of the business. The farm has been dubbed the 'Disneyland of agricultural tourism.' It has a Marriot hotel, restaurant, cowfé, and three adventures in crops, dairy, and pigs attracting half a million visitors per annum. The second is milk branding selling milk to Coke-a-Cola who process into an ultra-filtered, lactose free, high protein, long life milk called 'Fairlife.' The products under the Fairlife brand are aimed at the health, environmental and animal welfare conscious consumer.

Setting aside the fascinating story of the tourism and supply chain aspects of the business, the McCloskeys have developed a circular system with value added at each step.

- Focus on soil and animal health to drive efficient production.
- Anaerobic digestion to produce biogas and renewable electricity from manures.
- A compressed natural gas filling station to enable a fleet of trucks to be run on carbon negative fuel.
- A bio fertiliser plant in collaboration with Gary Zimmer's company Midwestern Bio-ag producing a range of bio fertiliser products.

The farm is spread over 25,000 acres, which is used to grow the feedstuffs for the diary, this cropped land is fertilised by the refined wastes from the livestock. The technology on display at Fair Oaks to add value from the back end of the cow to the field involves several different processes.

1. The manure is fed directly into a plug flow anaerobic digester manufactured by US company DVO. The outputs from the digester are biogas, which is scrubbed to remove the carbon dioxide and hydrogen sulphide. A portion of this is burned in a gas engine to produce electricity to power and heat the farms. Any surplus is exported to the electricity grid. The remaining bio-methane is compressed to 275 bar (compressed using electricity from the gas engine). It is then used in what was one of the first dairy to bio-methane filling stations in the US opening in 2011. Adapted HGVs use the biomethane instead of diesel, saving up to 100% of carbon emissions per km travelled.
2. Cows are bedded on sand which requires separation from the digested manure using a sand separation system. An inclined auger in a trough, uses gravity to settle the sand to the

bottom of the tank where the auger slowly moves the sand uphill to exit the separator to be reused for bedding.

3. Fibre is separated from the sand free manure, using a slope screen separator.
4. The separated liquid enters the Trident manure processing system which consists of three stages. The first is a flocculation tank, where a polymer is added to stick the suspended particles in clumps. This allows a dissolved air floatation tank to skim off the flocculated sludge.
5. The flocculated sludge is passed through a disk stack separator, which has a low power requirement and separates the DAF sludge producing 35% DM sludge. This is stored with the separated solids from the slope screen separator in step 3. The entire process is powered by renewable power from the digester.
6. The sludge and fibre from the Trident system is moved to a separate facility where it is used as the base for a bio fertiliser treatment process. This makes a spreadable product marketed as Terra Nu by Mid-Western BioAg. The bio fertiliser comes in several forms, all based on a homogenous granules made from the digested manure. These have a full suite of macro and micronutrients, with up to 6% nitrogen, 10% phosphorus and 8% potassium. Other formulations include a 3:3:3 nitrogen, phosphorus, potassium and a calcium boosting product. Terra Nu is high in carbon, which feeds soil microbiology as well as supplying complete plant nutrition, resulting in an increase in crop yields over eighty-eight trials in seven US states.
7. The remaining liquid is extremely low in suspended solids, and as a result has little nutrient or odour, allowing it to be used in the farm's irrigation systems.

Mike McCloskey has not stopped there; he has developed a system to take the process a step further and in a single plant processes the digestate into:

1) Clean water.
2) Dry, pathogen free, and stable solids for use as bedding and/or soil amendments.
3) Concentrated liquid, organic nitrogen fertilizer.

This enables the farm to become a zero-discharge dairy. As can be appreciated this 'holy grail' of manure processing has commercial sensitivity until its release. However, from the conversations about the technology, the McCloskey's will have a fully circular farming system, producing food and energy on a grand scale.

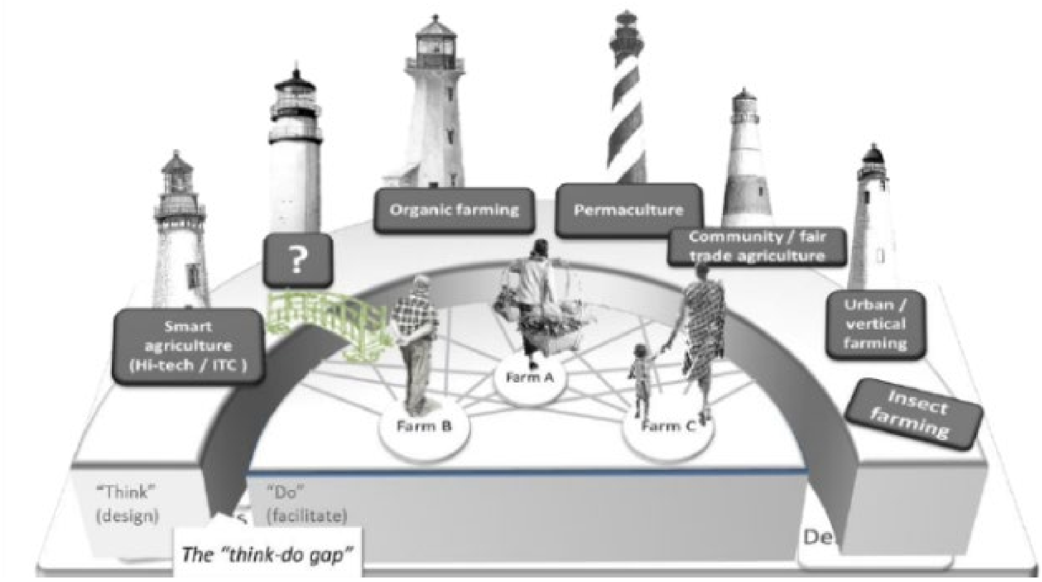
Wageningen University

On a national scale the Netherlands is a leader not only in agricultural output, but also in the circular economy. The Dutch government has committed to a zero-waste economy by 2050. It has a transition plan in place, setting specific goals in this transition to fully circular economy running in parallel with the Dutch climate agreement to cut emissions to 95% of pre-industrial levels by 2050.

Wageningen university is a leader in circular economic thinking and farming research and analysis where Professor Rogier Schulte is the chair of Farming Systems Ecology Group. The department's mission is: *"To equip all the 'actors' in the food system with the keys to unlock, redesign and transition farming systems by experiencing, analysing, and learning from outstanding examples of* *farms and foodscapes around the world."* The outstanding examples are identified by 'lighthouse farms' guiding the way to sustainable food systems by 2050.

Rogier Schulte, his team and students have identified that: *complexity + knowledge = food + ecosystem services*. The lighthouse farms are examples of this equation, demonstrating the possibilities for others to follow. The lighthouses have several distinct categories in recognition of different political, economic, social, technological, legal, and environmental factors globally. All the categories represent innovative and financially viable solutions in the categories of smart agriculture, regenerative, climate smart, permaculture, nature inclusive circular farming. The farming lighthouse network uses the expertise of Wageningen to develop tools that enable the gap between 'thinking' and 'doing' to be bridged.

The circular farming lighthouse farm provides an insight into what is possible with the addition of knowledge and complexity. One lighthouse farm is run by the Maj family in Belvadia, Latvia. The farm ignores the concept of 'by' and main products, the family milk 1,000 cows on 4000ha. Milk is the offshoot of manure production, the manure enters the farms AD plant, producing enough electricity for 2,000 homes, the offshoot of the electricity is heat. The heat is used to warm water in which sturgeon and eels are raised. In two years, the sturgeon grows to 10kg, the fish are processed and sold. The fish is not the end of the story, as the caviar from the mature sturgeon is the final product from the farm. The farm has carefully examined its flows and mass balances of biomass and energy and created a model that makes every asset, be it land, stock, the anaerobic digester, or the fish farm work to best use all the mass and energy from each interlinked enterprise to maximise the flow of money.



Graphic: Wageningen University

The second of the lighthouse farms is the Dowth Estate in Newry, Ireland. The estate is overseen by John Gilliland, the Director of Sustainability at nutrition company Devenish.

The farmland includes 20% of the UNESCO World Heritage Site at Brú Na Bóinne in a 6,000-year-old landscape including Megalithic passage tombs. John and the team took on a blank canvas in farming terms when Dowth was purchased by Devenish chair Owen Brennan in 2013. The vision was to create a truly sustainable example of meat production, complimenting the past 60 centuries of farming activity. By mapping all the 'signals' to the farmer they were able to make decisions on the best fit solutions and the results are the development of climate smart red meat production. John Gilland labels the landscape as the 'performance house' for ruminants. John and the Dowth team have not stopped at the carbon intensity of meat production on the site but are looking at the health benefits of grass-fed meat, including the bioavailability of nutrients in beef and lamb raised at Dowth.

The knowledge plus complexity involved is proving the equation set out at Wageningen. Dowth have pioneered a precision landscape approach, using high resolution LiDAR (laser) technology, GPS precision soil sampling and accurate carbon foot printing to gather a huge amount of data on the farm. This information is processed, and the flowing outcomes are delivered:

1. *Measurement of total above ground carbon.* This is calculated from the total above ground biomass on the farm in hedges, trees, scrub, grassland, and woodland at a moment in time. The data can be regathered on a 5-10 yearly basis and the increases in above ground biomass and therefore carbon calculated.
2. *Measurement of below ground carbon.* Soil samples are plotted using GPS and taken from 0-30cm horizon using the International Panel on Climate Change protocol. The samples are then analysed for carbon as well as the more usual macro and micronutrients. As per the above ground carbon, this can be resampled at intervals to measure fluxes in carbon.
3. *Measurement of farm emissions.* Using the SRUC 'agrecalc' tool the emissions of the farm are measured to ISO 14067:2018. The emissions can then be deducted from the carbon stored on the farm over a period. Using this information David Hagan has calculated that at two livestock units per ha, the beef produced at Dowth is carbon neutral, when 665 tonnes of carbon dioxide equivalents are sequestered in the above ground biomass and below ground soils of the farm.
4. *Overland flows.* The LIDAR survey also gives the ability to plot the catchment area of each watercourse very accurately. Overlayed with rainfall data, this gives the precise location and size of the pollution potential of each catchment on the farm. Biological interventions designed to cope with the waterflow, and nutrient loading can be planted in the locations identified by the LIDAR survey analysis. Short rotation willow coppice is a good fit as it can use the captured nutrients and water to supply biomass for energy production or animal feed.

The team at Dowth have added further management interventions to increase the carbon sequestration at Dowth by improving soil pH, increasing the use of legumes within the sward, reducing the age of trees and hedges to encourage more vigorous growth, and incorporating agroforestry in the grazing platform. All this will reduce the carbon footprint of the livestock production on site or allow increases in stocking rate. All the discussions with John and the team are thought provoking, however a discussion on the possibilities for the use of surplus forages for energy production, using anaerobic digestion rather than increasing stocking rate, gave an interesting perspective to take away.

Lessons learnt for systems design and implications for the Circular Farm

Rogier Schulte's equation *complexity + knowledge = food + ecosystem services* reinforced the need to embrace complexity on farms. Although farmers' jobs already include an incredibly diverse skill set, the future will require farmers to disseminate more information on concepts such as carbon foot print, environmental impact, nutrient and water use, biodiversity assessment, the list goes on. To distil this into day to day and strategic decision making is not easy. There is only so much information one farmer can process. Tools such as collaboration (many brains make light work?) and artificial intelligence will play a role in the future decision-making process. This will enable the farmer to embrace complexity and develop knowledge. The tools of the system thinker are crucial to the ability to look at relationships rather than in isolation, wholes not parts, disconnection into interconnections. Fair Oaks, The Maj Family and Devenish are all lighthouses that can guide thinking in what can be a foggy ocean!

Chapter 4: Soil at the Core

The soil is the centre of any farming system. The need for healthy soil to underpin a heathy society, was highlighted by John Gilliland in Dowth with his summary of the benefits of animal nutrition for the human diet, “one health” from soil to society.

“Yes, you are what you eat!”

Australian Graeme Sait has spent the past 25 years researching the relationship between soil, human and planetary health. Graeme’s nutrition farming course is a well-structured immersion in the vast amount of information Graeme has gleaned from some of the best minds in soil, health and climate science including some now familiar names such as Joel Salatin, Gary Zimmer and his co-presenter Joel Williams. The nutrition farming course covers soil health in detail, Graeme presents 10 reasons to embrace biological agriculture:

1. Chemical agriculture is the definition of unsustainable, as more agri-chem used each year, treating the symptom not the problem.
2. Using child health as a marker for the success of society. Child health is declining.
3. Monitoring of soil fauna has revealed a decimation of key creatures in the soil such as earthworms.
4. Poor soil health leads to poor animal and human health.
5. Conventional agriculture is the biggest single contributor to greenhouse gas emissions.
6. The only saviour for climate change is agriculture.
7. Building humus is key to reversing climate change (1% increase in humus across US soils would remove 4.5 out of the six billion tonne contribution to the problem).
8. Building humus is a biological process so anything to the detriment of that is unacceptable.
9. Systems based on oil (fertilisers, diesel, fungicides, herbicides, and pesticides) has a definite use by date.
10. Passion is priceless in your chosen profession! (Graeme has this in heaps!)

One of the many take home messages was the need to build humus in the soil. Humus is the glue which holds soil together built by microbial communities and contained in high portions in composted organic matter, such as manure, green waste or vermicompost. The addition of these products to soil drives the ability to store carbon and water, it impacts the nutritional values of food as it can store all 74 minerals and hosts microbiology making these minerals available. Higher humus allows the plant to self-defend from pathogens reducing the need for chemical inputs. It is a carbon filter holding onto nitrate nitrogen and heavy metals. Finally, it improves soil structure allowing the soil to breathe.

To be truly circular a farm must have the ability to cut out fossil fuel manufactured inputs. The need to build humus and keep nutrients in the sil reinforces the circular principals to regenerate natural systems to recycle organic material and not allow the escape of valuable nutrients or chemical inputs from the farming system into the environment. Being savvy with the soil is a foundation of the circular farm.

Conclusion

The development of the Circular Economy and the Circular Farm present agriculture with a winning solution to help address the overshooting of planetary boundaries.

Areas of focus around climate change, impact of nitrogen and phosphorous use require significant and swift action, within the backdrop of feeding a growing population. Implementing the principals of the circular economy; designing out waste and pollution, keeping products and materials in use and regenerating natural systems in an agricultural landscape creates a framework for farmers to adopt circular systems.

Customers of the products of agriculture are looking to suppliers to reduce the emissions and environmental impact of their operations, from Aldi to Nestle, Danone to Tesco, the footprint of food production is firmly on the map. Renewable energy only offers half the solution. The remainder must come from adopting a systems thinking approach to take into consideration the whole 'foodscape'. The circular economy can link the consumer, supplier, and farmer together in a self-supporting network.

We must now embrace complexity; zoom out from individual products we produce and look at how the entire system works. Careful management of the interrelationships between each part will enable farms to become a foundation for future prosperity and sustainability.

Recommendations & principles for the Circular Farmer, the Policy Maker, and the Author

The Farmer:

a) Design is better than default, designing out waste across the farm from lean management to reduce wasted time, through designing manure handling to reduce ammonia loss, measuring soil carbon, examining overland flows to reduce diffuse pollution, or collaboration with producers of biofertilser.

b) Embrace complexity, complexity has a critical mass, and a minimum level is required to benefit from the synergies available.

c) Knowledge is essential, but you do not have to know everything, as per the well-known saying ‘a Jack of all trades is a master of none… but often better than a master of one’. Collaboration with experts will build and support the farmer’s knowledge.

d) Develop a system thinking toolbox. Those tools are the ability to see interconnection, synthesis, and the whole rather than parts. To think in circles not lines and remove silos that funnel thinking into the boxes.

e) Embrace diversity, the more diversity the more components to the farming system. Diversity mitigates risk and is strength.

f) Identify functions that each component can fulfil, for example is it food, fuel, building material, soil amendment or energy production?

g) Put the right component in the right place at the right time in the right amount, be it the complimentary crops on a field scale or the precision management of a landscape.

The Policy Maker:

h) Adopt a zero-waste strategy to align with carbon dioxide reduction goals. Organisations such as PACE pacecircular.org and the Ellen McArthur Foundation ellenmacarthurfoundation.org are well resourced with specifics for policy makers and follow the lead of the Dutch and the Danes.

i) Remove barriers. The principals of the circular economy make sound environmental and economic sense. They also present opportunities for GDP increases (if there is an insistence on ‘growth’) and economies to operate within the planetary boundaries and above social foundations. There are certain non-financial barriers in place such as regulation. These hinder the advancement of the circular economy. The 2021 update to farming rules for water are an example. They have unintended consequences and could serve to prevent the application of vital humus to the soil.

j) The farming sector requires a system thinking analysis to highlight opportunities for research and development. There never is a ‘silver bullet’ but analysis and understanding of complex systems such as modern food production is not easy or cheap but targeting and enabling the scaling of waste reduction technologies, which create inputs for agriculture such as the examples of CCm Technologies and Ostara should be part of the procurement or tendering processes for waste management infrastructure. Developing mutually beneficial products that benefit the environment, economy and secure a supply of sustainable farm inputs is a good example of win-win thinking.

k) Support anaerobic digestion to cut methane emissions, offset fossil fuel and provide a renewable fuel compatible with existing infrastructure.
l) Promote a precision landscape approach where supported interventions, such as watercourse buffers and woodland planting are placed in the landscape to serve a multitude of purposes rather than just one. Give the farmer the tools to measure the progress rather than consume time with the process.

The Author:

m) Employ a system thinking approach and look at where value can be added on the farm by seeking out expertise in flows of mass and energy, with the goal of developing a net zero business by 2030. This will include:
    i) Increase the soil 'savviness' of the business, developing key performance indicators for a healthy soil.
    ii) Maximise the use of by-products across the farming system as inputs to the dairy and arable operation, from soil amendments to food residues.
    iii) Continually evaluate the carbon intensity of operations using an accredited carbon calculation tool.
    iv) Employ a precision land management approach. Using LiDAR technology overlaid with exiting mapping data such as yield to identify:
        (1) Above and below ground carbon.
        (2) Overland flows, to identify areas for interventions, such as short rotation coppice.
        (3) Poor preforming areas and opportunities to highlight these for biodiversity increases, carbon storage or fuel production.
    v) Explore the opportunities created by anaerobic digestion to highlight opportunities for:
        (1) Gas and or electricity and heat production.
        (2) Bio fertiliser.
        (3) Reduction in carbon intensity for on-farm energy use (electrical and or bio-methane powered machinery).
        (4) Additional enterprises to compliment the flows of energy and biomass around the farm, for example fish and fly farming?
    vi) Evaluate the possibilities for additional renewables to complement the existing infrastructure.
    vii) Remember that knowledge is key. To keep expanding the knowledge of not only myself but the team on the farm. Keeping an 'ear to the ground' for circular solutions and encouraging tests and trials of these solution on the farm wherever possible.

Acknowledgements

I would like to acknowledge and thank the following organisations and people for their help, support and guidance throughout my Nuffield Project.

Nuffield (UK) Farming Scholarships Trust and the NFU Mutual Charitable Trust for awarding me the Scholarship and giving me the opportunity to further explore the ways to have influence in the journey to more sustainable food production.

To all my colleagues at Grosvenor Farms who have been so supportive and encouraging of my ideas and covered my work when absent on my travels.

To everyone who hosted me abroad and were so generous with their time, information, and hospitality and all those who I interviewed or questioned.

My fiancée Rebecca and my network of friends and family who have helped in so many ways.

The Circular Farm
9 781912 059379 >

Published by Nuffield Farming Scholarships Trust
Southill Farm, Staple Fitzpaine, Taunton, TA3 5SH
T: 01460 234012 | E: director@nuffieldscholar.org