A Nuffield Farming Scholarships Trust Report

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Powering pasture and the relevance of red meat in the 21st century

Alex Brewster

September 2019

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NUFFIELD FARMING SCHOLARSHIPS TRUST (UK)

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A Nuffield (UK) Farming Scholarships Trust Report

Date of report: September 2019

"Leading positive change in agriculture. Inspiring passion and potential in people."

Title	Powering Pasture and the relevance of red meat in the 21st century
Scholar	Alex Brewster
Sponsor	The MacRobert Trust
Objectives of Study Tour	• To provide livestock farmers with the tools to develop a profitable and sustainable business by maximising genetic and pastoral efficiency. • To demonstrate that grass-fed livestock produce high quality and healthy red meat. • An unexpected objective is to show how red meat production is part of the environmental solution and not part of the problem.
Countries Visited	Scotland, Wales, Ireland, England, France, Holland, New Zealand, Uruguay and Chile
Messages	• The future of red meat is green! • Proactive grazing management is a must to achieve the win-win of profitable and environmentally sustainable livestock production. • Our goal should be to create an eating experience that has the wow factor and demands a premium justified by its environmental credentials. • Livestock production must be in-tune with local ecosystems. • Our knowledge and active understanding of the basic needs of pastoral plants, like grass, is woefully short for businesses that rely so heavily upon them for economic sustainability. • Pastoral plants are the world's lungs with the potential to absorb twice as much CO2 as the world's forests. Their primary function is not to be grazed but to act as an energy transfer mechanism. • The UK's maritime climate is ideally suited to growing grass.

Executive summary

The author farms at Rotmell, in the Highlands of Scotland, where Less Favoured Area farming has always been a challenge, limited by topography and dictated by climate.

With less than 13 per cent of the land mass farmed by the author designated as 'improved pasture', cultivating his way out of trouble cannot be seen as an option. The intention of the study was to look for a way to increase profitability and create a more robust business model that would be more resilient to external pressures.

The study began with the author convinced that the science of genetics would hold many of the answers. But the conclusion is that this is only partly right. For any genetic gain to be able to express itself in the animal you have to able to feed it. The more consistent the pasture, and the higher the quality, the greater the economic gain. The vital factor in achieving this is soil health and fertility.

This Nuffield Farming study tour commenced by visiting many of the great research institutes in the UK: the technology and scientific understanding found there were inspiring. However, once on the road and physically in the fields of three continents, the best operators were found to be people who understood the simple limits of their environment. They accepted these limits and then managed them to their advantage.

Farming is limited by the biological communities living in the soil. It is the biology in the soil that brings a greater resilience to land performance. It allows us to harvest and store more energy from the sun and rain. If the biology in the soil is enhanced it will host a greater number of beneficial bacteria and other forms of microorganism which have evolved to form mutualistic and symbiotic relationships with the botany that surrounds them.

Through his study the author has concluded that a greater range of diversity brings a biological and genetic robustness that cannot be so easily undone by natural forces. Farmers manage a food chain and it starts beneath their feet: in essence an energy cycle. Building this biomass increases soil's organic matter and this is what 'powers pasture'. It creates a greater nutrient density in plants which in turn increases live weight gain and reduces nutritional stress to both plant and animal. All of this aid's fertility: enhanced fertility is a key driver in farm profitability.

Our herbivores are an energy transfer system, biologically linked to the pasturelands and soils. Is it any coincidence that rumen and soil pH are aligned? Ryegrass is thought to have evolved 72 million years ago. Animals were needed to graze it and thus play their part in completing the nutrient cycles. To understand the relevance of red meat in the 21st century, there is a need for a deeper understanding of these biological processes at work and building pasture management systems that allow grasses to be themselves: the controllers of the ecosystem. The future looks good and tastes better!

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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.

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Chapter 1: Introduction

Figure 1: Alex Brewster, author of this report on his farm (Source: Author)

I am an upland beef and sheep farmer in central Perthshire, Scotland. I manage a tenanted farm along with my wife Jane and we have two children, Katherine and Forbes. At 55 degrees north and 250 meters above sea level, we get four seasons, sometimes on the same day!

My family have always been farmers; both of my parents come from farming families and my wife is the daughter of a farmer. With the arrival of our first child in 2010 I started to question: was farming really a bubbling thriving industry that I could recommend to her? For too many years it had felt like we were treading water, even though we were investing in the best genetics and adopting new EID technology to build performance on data. We built data sets when other farmers built sheds. It became disappointingly predictable that every year the performance always showed the same trends and gain was a consistent two per cent. By 2012 I was looking at other ways to get more than two per cent.

We stumbled into rotational grazing by gathering up the set stocked animals, pushing them into bigger groups and started to move hundreds of head into the next field once the current one was grazed bare. It wasn't scientific and it wasn't slick, but the data showed an increase in performance above the usually two per cent. Was rotational grazing the answer I was looking for?

The primary driver for my application to a Nuffield Scholarship was to use the opportunity to explore the world in search of best practice in maximising genetic and pastoral efficiency. I wanted to find and meet the individuals who understand what drives pasture. How many different grazing models are there? Is there one ideal that is more applicable to UK conditions? What I have concluded is that optimisation has to be the new maximisation!

Chapter 2: My Study Background

A. Are the aims and objectives of your study the same or have they changed?

I started out by looking at how to improve the efficiency of beef and sheep production but during this exploration I ventured into the potential win-wins of carbon sequestration, which in turn led to exploring water and nutrient cycles. This became a foray into holistic farm systems and how diversity is a driving force in achieving ecosystem resilience. I then developed thoughts on how we, as an industry, can start to produce red meat that not only tastes amazing but is also far more nutritious for human consumption.

B. Aim of the study

My aim is to understand what drives pastoral efficiency on farm. To get to the bottom of this I have asked three questions, all underpinned with the premise that red meat must be produced sustainably:

1. How to best utilise the grass you produce
2. Which class of livestock optimises pasture utilisation
3. How do we combine these to drive the weight (kilograms) of meat (live weight) sold?

I became interested in finding out how to retain more of every £1 in the farming family's pocket, and how to do this with less environmental impact.

So, is there a positive and direct link between intensive and profitable red meat farming systems and environmental uplift?

Is there such a thing that gives red meat farmers a win-win for the environment as well as meat taste? Or is environmentally sound, red meat production a doomed hypothesis?

C. Objectives of the study

The study of pastural botany that creates sustainability in soil management and how economic return is governed by grassland utilisation.

In my experience, cattle and sheep farmers concentrate their management decisions on the physical attributes of the animal. They look at animal welfare and performance – is this cow in calf? Is this ewe in lamb? How heavy is this lamb?

Day to day livestock management overlooks the soil and plants, primarily because these components are constant and either too difficult or too expensive to change. Much of the current soil and plant management is broad-brush: we analyse soil pH and nutrients, then apply fertiliser and lime. We choose grass species by yield potential rather than its nutrition.

I began to realise that I would need to define red meat production into a cycle of four on-farm components. Understanding and analysing these four components can drive change at farm level by altering farm practices. To drive this change, Key Performance Indicators (KPIs) measure and change

the everyday language used to describe whole farm efficiency.

1. How to optimise the soil's biological and nutritional potential. What to look and test for and how to drive the optimal soil KPIs.

2. The interaction that different pasture plant species have within the soil and their effect on soil biota. Use this knowledge to create the optimal soil that will grow the appropriate pasture plants better.

3. Selection of the right animal genetics for the farm environment. What KPIs are appropriate for the highest weight yield? What economic factors influence this decision? Perhaps carcass weight sold, but should we also consider ewe/cow mature size and the fertility of the breeding stock?

4. Interaction between the cycle of soil, plant and animal, and how management of each of these parts affects the efficiency of red meat production.

D. Summary of study

My Nuffield study investigates how UK pasture farmers can get the best beef and lamb from the way they farm their grasslands, while safeguarding the environment. I wanted to explore how to get the best out of pasture farming. In technical terms I am interested in optimising the utilisation of pasture for red meat production that carries high environmental credentials.

Red meat (beef and lamb) is food; it is a protein and energy source. Red meat is produced on the extensive grassland areas of the world that have physical or ecological issues not suited to arable cropping. My study focuses on the physical and ecological influencers that affect UK red meat farms.

Evolution has created formidable grazing machines, herbivores that can eat, grow, reproduce and defecate in a natural cycle of nutritional management. Each part of this cycle includes a transfer of energy and nutrients that ultimately results in red meat that is food for a family meal or a pack of lions in Africa; the mechanism and fundamental process of energy and nutrients in the cycle is the same. It is the intricacy of the component parts of this process that we as farmers must understand better to allow a more sustainable approach to red meat production.

Meat production rotates around energy produced and consumed through various stages. The sun is the primary source of energy in the world, but it is how everyday farmers harness that energy for growing food that interests me. Photosynthesis is the primary means of absorbing light energy. The greater the leaf area and denser these leaves, the more energy that can be captured per Ha. This allows the powering of capillary action or osmosis.

Globally, the greatest limiting factor in this energy circle is water. Plants need water to grow but water is stored primarily within the organic matter of the soil. The amount of organic matter present is affected by many different things, but a one per cent increase in soil organic matter content has the ability to hold an additional 250,000 litres of water per hectare (Ha). With our maritime climate you might think that water content in UK soils is not such a big issue, but it is the soil's ability to manage this moisture that dictates our ability to produce and utilize grass efficiently.

At a local level, on our farms what should we be looking to adjust so that we optimize the kilograms of feed dry matter that can produce? How do we make the best of our pasture? What numbers and type of animals do we need to keep this nutritional cycle rotating?

E. My target audience

The primary audience for my report is working farmers but it is also relevant to policy makers and consumers as I am challenging the old way of thinking about carbon cycles, nutrient management and efficient increases in red meat farm production. There is a real sea-change required in food production and, if we don't return to the basics of soil and livestock management, we are banging the sustainable drum with one hand behind our back. Also, I want to show that red meat is a good thing to consume, not just for human health but for the health of soil and plants as well. I believe that holistic red meat systems demonstrate environmental credentials that can strike a chord in the consumer who is concerned about pollution, climate change and waste.

F. My headline take-home message

Proactive grazing management is a must to achieve the win-win of profitable and environmentally sustainable livestock production. Pastoral farmers farm livestock on pasture and then sell energy, nutrition and water in the form of red meat. Our goal should be to create an eating experience that has the wow factor and demands a premium justified by its environmental credentials.

So how do we optimise our livestock production yet maintain our environmental credentials? The answer is to be in tune with local ecosystems and put management of the pastoral ecosystem under the spotlight.

Our knowledge and active understanding of the basic needs of pastoral plants is woefully short for businesses that rely so heavily upon them for economic sustainability

Whether managed by the farmer or ignored, pastoral plants will always grow. They are the world's lungs with the potential to absorb twice as much CO2 as the global forests. Through my research I have come to realise their primary function is not to be grazed but to act as an energy transfer mechanism.
Grasses use solar energy to produce carbohydrate from atmospheric carbon dioxide and water. The plants' botanic mass reduces water runoff and creates channels for the water to descend into the soil. Held in suspension within Soil Organic Matter water ascends or descends through hydrology, neither leaching nor evaporating if the soil biology is healthy.

The UK is blessed with the ability to grow grass; our maritime climate gives us a natural resource that many in the rest of the world crave for: WATER. It gives life, grows grass and allows biology to flourish. It is a serendipitous thought, that we constantly measure a biological process chemically.

Chapter 3: My Study Tour

Scotland	SRUC, Roslin Research institute, Dr Joanne Conington, Professor Mike Coffey, Professor Eileen Wall. Sustainability of breeding program, Meat eating quality and genomics. Morden Research Institute, Dr Philip Skuce & Dave Bartley, Genetic resilience and diversity. I was interested in understanding the roll genetics played in disease resilience. SRUC, Kirkton. Dr Anne Maclaren, & Dr Nickola Lambe. Genetics and the Environment, Phenotype Vs Genotype, how these interactions take place on a hill side and which part has the most relevance and financial impact. Dr Alison Bennett, James Hutton Institute, Rhizosphere microbiologist. I visited JHI and Dr Bennett who specialises in plant mutualist arbuscular mycorrhizal (AM) fungi. My interest was to understand how fungi helped move nutrition around between plants and soil.
Wales	Innovis, Dr Janet Rowland and Dewi Morris. Composite sheep breeders and marketers of Aberfield genetics across the UK. What were they striving to achieve in the sheep sector as they build the Aberfield brand? Chris Mossman, an exceptional grassland dairy farmer who has a talent for optimising milk yield and pasture utilisation. How to make the connection between pasture utilisation and profitability. Neil Perkins, Penbuckshire, South Wales. Sheep farmer who is running his own genetic breed program and rotational grazing system.
Ireland	EAAP, Belfast. Animal Science conference. A good event to listen to many interesting presentations and gather some thoughts before future travel. CAFRE, Greenmount Campus, Dr Eileen McCloskey hosted my visit to the Northern Ireland upland research farm, where we discussed breeding programs and EBV in upland farming situations.
England	Dr Julia Cooper, Newcastle University. A speciality in Soil Organic Matter. I was seeking a greater understand of what organic matter was and how to build it. It's the biological part of soil. Christopher and Shelia Cook, 3LM. This was my first introduction to Holistic Land Management; it wouldn't be my last. An exploration into seeing the natural world as a whole, but with 4 distinct ecosystem processes. Mirriam Parker MBE, this was an interesting visit looking at animal behaviour and management through handling system as well as reducing animal stress in general.
France	John Bailey, Pastore Sence: Rotational grazing systems in France.
Holland	Gallagher Europe: technology and innovation in managing animals at pasture.
New Zealand	Farmax, Hamilton NZ. As market leaders in Farm Financial Software it was interesting to get an insight into how environmental management might get brought into Farm business modelling and financial KPI.

New Zealand cont.	Headwater, Wanaka NZ. What started out as a composite sheep breeding project for maternal genetics turned into a lamb finishing and niche marketing product for a high value lamb into global markets. Ross & Ruth Richards, Romani Coopworth. The Richards are composite sheep breeders who have been refining their flock to be resilient to parasite and worms as well as being relevant for the ram buyer. Dean Morton, Glenland Farm, Napier. Self-taught regenerative grazier, who has challenged convention. Specialist in building biological communities in his soil to build organic matter and retain water.
Uruguay	INAC, Uruguayan Beef Industry Marketers. I was interested in how they had rebuilt the international reputation of Uruguay Red Meat industry after the Foot and Mouth outbreak. How they had installed global confidence back into their product and where it was now placed in the global marketplace.
Chile	Manuka dairy, a New Zealand owned dairy Co-op in Chile. Is big beautiful and can production and profitability be achieved on a large scale? Rabo-Bank, a global banks perspective on the benefit of agricultural cooperatives. Fruticola Terranova, Austral Berries. A first-generation soft fruit business, marketing and branding blueberries globally, how have they achieve this? John – from Cork, building a dairy farm from scratch in Chilean bush, how working with nature and managing natural resources can create a profitable family business.

Chapter 4: Soil is the engine room

Soil is full of living organisms and their health status influences so much more than simply producing a crop. 'We are what we eat' is a very apt phrase when describing soil health and resilience. Having started my Nuffield scholarship with my big theory about nutritious and environmentally-sound red meat, I started to think about what the pasture farmer needs to produce this type of red meat. Clearly you need livestock, and these need to be fed as efficiently as possible if we want to achieve profit. Cattle and sheep are ruminants and eat grass and pasture. My steps into rotational grazing had taught me that pasture was probably more apt than the term grass. And the next thought was that good pasture fundamentally needs good soil. I realised I had never really thought about the intricacies of good soil management. Like most farmers I just expected my soil to grow the grass I needed.

A. Soil components

In ideal conditions soil is made up of 25 per cent water, 25 per cent air, five per cent organic matter and the 45 per cent minerals. My challenge to farmers is to rethink the way you manage these components. You DO have control over the composition of the soil, and in fact you have a responsibility to get the balance of the components correct.

I asked myself the question 'Does there need to be such a strong focus on the mineral element of the soil when its effectiveness is so intrinsically controlled by its ability to breathe?' After all, soil organic matter consists of billions of microscopic life forms all living symbiotically in what is better known as the soil food web. I began to think that if the main soil components were mostly in balance, soil organic matter was probably more important than any of the other composite parts of soil.

For so long soil health has simply been a classification system that measures the major nutrients in the soil. This has given a simplistic view of this little-known world beneath our feet. It is far more than just nitrogen, phosphate and potassium which, for many years, were all we seemed to see on soil analysis sheets. It has taken too long for farmers and farm advisers to look beyond the chemical elements in the soil and for there to be a general realisation that there are more than 20 chemical elements needed to provide the plant with all the nutrition that it needs.

No single soil nutrient is more important than another. Nitrogen may be needed in the greatest quantity, but it is no more important than silica. Soils with an adequate level of calcium can be common, but unless boron is available to mobilise the calcium then its nutrient availability is hampered; that said, boron needs silica to make it mobile within the soil. Soil chemistry relationships are complex and understanding these is extremely important if farmers are to have the knowledge they need to look after soils better.

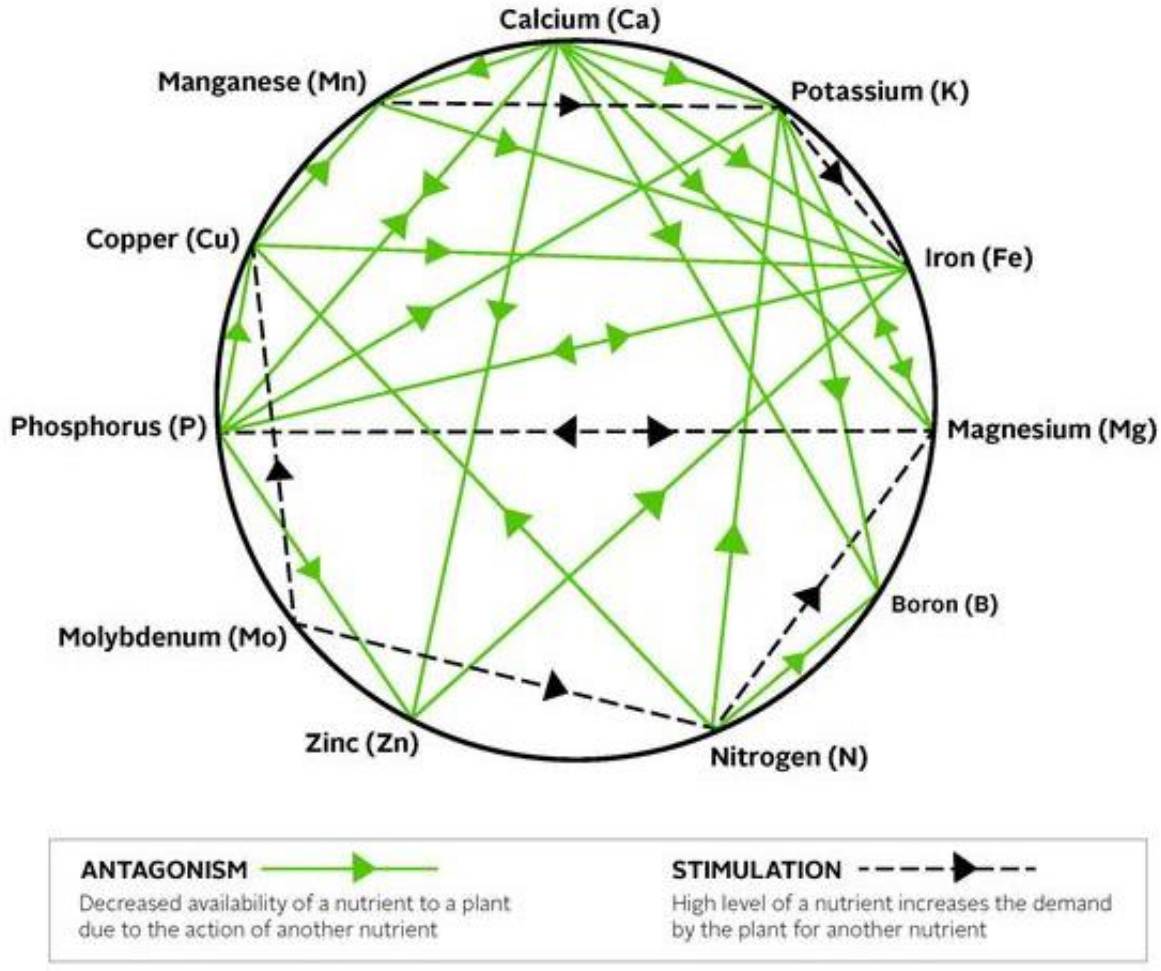

Figure 2: Mulder Chart of nutrient Interaction (courtesy of Nutriag.com)

Mulder Chart (above) showing different mineral interactions

The movement of nutrition from the soil to the plant is governed by the ability of the plant's root hairs to find the soil nutrients. Soil nutrients lie within the soil profile waiting to be mobilised to the plant via the root hairs. The farming system and its soil management are key to getting the root hairs working in the soil profile. This is like having a healthy bank balance but no cash card for withdrawing funds.

B. Soil organic matter

Dr Julia Cooper, Lecturer in Soil Science, Newcastle University, in a personal communication, March 2017: ***"Ecological intensification, it's a way of farming to optimise natural processes, capturing carbon from the atmosphere - that's the number one thing we are trying to do in farming is to capture carbon from the atmosphere, turn it into carbohydrate and use it somehow. But ecological intensification that is [sic: needed] to optimise that, we're looking at natural ways, using legumes that fix nitrogen, that's a biological process that we can enhance more, using more nitrogen fix crops instead of buying fertiliser. Diversifying crop rotation, when we do that, we create more natural controls of pests and diseases, when we get diverse crops into a landscape, we get more insect predators and from these ecosystem servicers a more natural process that work for us better and reduce external inputs."***

I met Dr Julia Cooper, a Lecturer in Soil Science, at Newcastle University where she spoke to me about soil organic matter. What she told me became the crux of my Nuffield study: "There are questions surrounding the no-till claims about carbon storage as soil can only hold a certain amount of carbon. There is an equilibrium soil carbon content, and this depends on the balance between net inputs and outputs. We want healthy active soils with the microorganisms absorbing carbon for respiration. Peat bogs are not necessarily healthy soils; they are soils with very slow decomposition."

Organic matter in the soil is the main source of carbon storage and is nicely described as the soil's sponge. It is the living component of soil that flexes and provides a degree of resilience to altering climatic conditions on a day to day basis. Soil Organic Matter (SOM) is the biological component of soil and carbon feeds the organisms that drive biological activity in the soil. Organic matter helps gain the biological balance between the living plant, decomposing materials, minerals and soil organisms. For so long soil has been discussed by its chemical components. These are easily measured, and any perceived shortfall addressed by adding minerals. BUT the mineral element is only available to the plant if the soil biology is alive. These living organisms in the soil are the beating heart of any land and are what will make or break your business. Note: a one per cent increase in SOM = 250,000 litres or 250 tonnes of water held suspended per Ha. This water is then available for plants for considerably longer, not running off or leaching, but waiting to be used for our benefit.

A higher levels of root mass will increase SOM. When a sward is grazed, the plant starts to recover by shedding the proportion of the root system that it cannot feed with a reduced leaf area, or photosynthetic area. These shredded roots die and then start to decay in the soil, aided by microbes, bacteria and protozoa. These living organisms are chewing their way through the decaying root mass breaking it down and recycling the nutrients and suspended minerals.

C. Microbial Function

Microbial function comes from bacteria, protozoa and nematodes. They shred and decompose organic matter to make it available to the fungi in the soil environment. Soil microbial function is a recycling process and unfortunately its value to the ecosystem is mostly overlooked. Microbial function is critical to the foundation health of the biology supported by soil. Soil microorganisms break down organic matter in the soil to the point when the organic matter becomes plant food.

D. Bacteria

Bacteria are everywhere. After fungi, they are the most significant decomposers in the soil. They are a single cell organism that can subdivide many millions of times in several hours. Root exudates are a favourite food of bacteria and as such many bacteria concentrate around the rhizosphere (the area directly around the root hairs) of plants. But they also employ enzymes to help break down organic matter into simple sugars, fatty acids and amino acids. Without bacteria we would be swimming in a sea of waste.

E. Protozoa

Protozoa are the microbes that eat bacteria. They control the population of bacteria. There are 3 basic types, each are different sizes, but all eat bacteria and start the nutrient transfer that is the soil food web[1].

[1] *Soil Food Web, courtesy of USDA-NRCS*

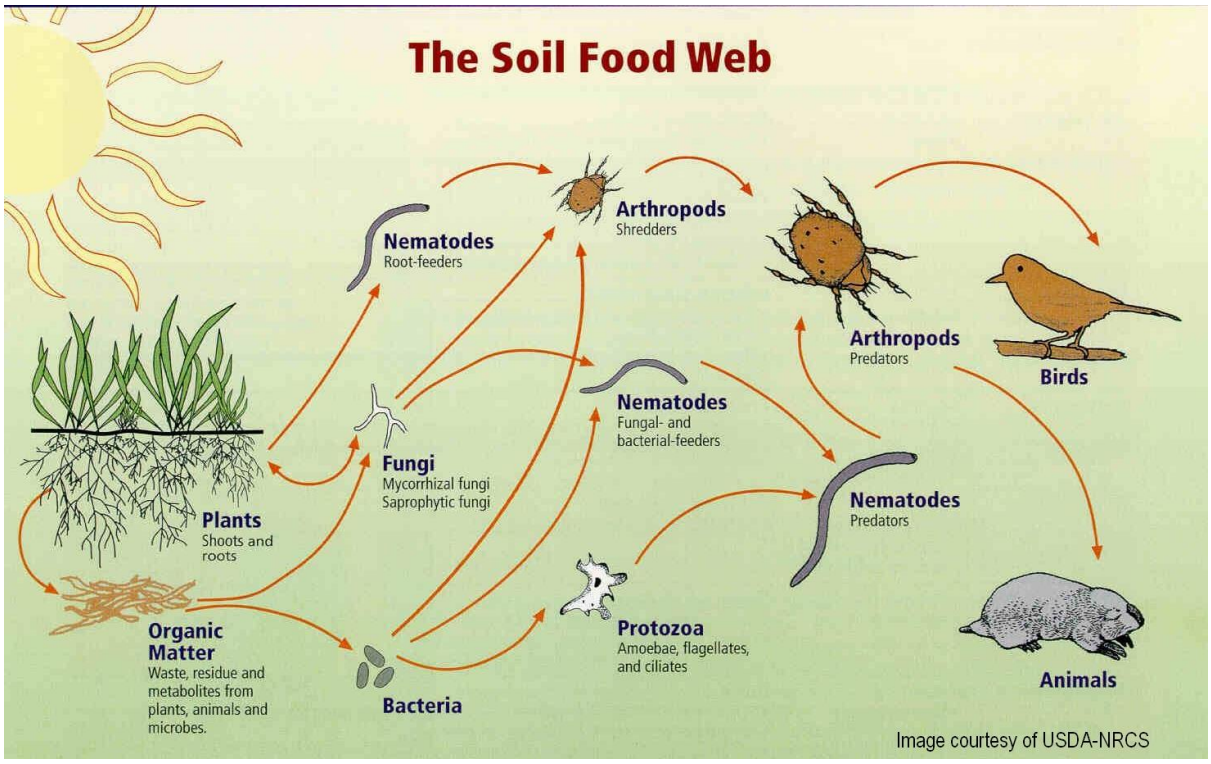

Figure 3: The Soil Food Web (courtesy of USDA)

F. Nematodes

Nematodes are blind roundworms which, along with some protozoa, mineralise nutrients contained in bacteria and fungi, as well as ingesting plant material. There are thought to be up to one million different species of nematode. But their primary function is mineralisation, i.e. breaking down, through ingestion and decomposition, soil minerals to make them available to the plant.

Microbe numbers are driven by a diversity of plant species: the greater the number of plants then the greater the number of microbes associated with each plant family. This is a called ecological intensification. Increasing microbial activity is the easy way to optimise carbon capture from the atmosphere. Plant exudates are the food source for microbes so the greater the microbial activity the greater the demand on these exudates. Plants, if managed correctly, can convert 70 per cent of the CO_2 they capture into these exudates.

G. Fungi

Fungi are the primary decomposers of the soil with the ability to move around all major nutrients as well as water through their hyphae. They can break down organic matter as well as capture and kill nematodes and protozoa, extracting the nutrients from them through the fungal hyphae tip and moved several meters away.

Fungi include mycorrhizae and are the network by which nutrients, water, energy and chemical signals are transferred within the soil environment.

I spoke to Dr Alison Bennet, a rhizosphere microbiologist in the Ecological Sciences group of the James Hutton Institute in Dundee. She told me about Arbuscular Mycorrhizal Fungi (AMF) that have been helping plants colonise land for four billion years when plants move out of the water. AMF provided the initial root systems before plants developed roots. This is one of the oldest free-living association or mutualistic relationships known. AMF have an association with more than 80 per cent of grassland and pasture plants as well as deciduous trees and are primarily a communication and nutrient movement system.

Dr Alison Bennett, personal communication, 2017: ***"It is significantly more important to manage your soils well; my priority would be to maintain diversity and understand how organisms work with each other."***

There are three different families of fungi on farm: AMF, Ericoidmychorrhizal fungi (which have more of an association with upland and heath plants and prefer a lower pH soil) and Ectomycorrhizal fungi who are associated with pine trees. Both Ericoidmychorrhizal and Ectomycorrhizal fungi provide nutrient movement and communication within their soil horizons with a primary function for nitrogen up-take, the one element which is generally slow to mobilize in low pH soils. Importantly, AMF is also responsible for phosphate (P) function in the soil profile.

Plant diversity and mycorrhizal fungi diversity go hand in hand to help maintain each other through plant soil feedback loops. Inorganic matter in soil contains a lot of locked up nitrogen and phosphorous. AMF can release these nutrients from the inorganic matter and deliver it to the plant through their hyphae (a very fine root structure of thin fibrous hairs that the fungi grow to search through the soil and move nutrients about). Hyphae can grow along with the plant roots and when they come across another plant Hyphe system they can connect and share resource between each other. The more hyphe webs that are connected the greater the resource sharing. Where pastureland is well managed, 20 different species of AMF can be found. The benefit to the plant in this relationship is the availability of difficult-to-access nutrients, a supply of water and an early disease warning system. When a plant is hit by a disease stress, the hyphae web responds by sharing chemical signals between plants joined by the hyphae. This gives the plant network a route to fight the disease, akin to antibodies in a mammal. What the fungi get back in return are plant exudates or glucose, realised through the plant root as a by- product of carbon sequestration.

Compaction is very bad for hyphae as they are so tiny and fragile that they are easily broken. Hyphae can regenerate fairly quickly; within 21 days you can definitely get re-growth and new connection. The more the hyphae are broken the more the fungi die. In bad soil management systems only around five are found. Fungi have a major influence on the growth of plants moving nutrients around. They are connected to lots of different plants and can move defense signals around which can change whole plant phenotypes, as these plants respond to being attacked by a parasite. Functioning AMF can increase plant root mass by up to 75 per cent thus giving the plant access to 75 per cent more nutrients and water.

H. Invertebrates

Invertebrates - worms play the pivotal action in soil physical motion and organic matter decomposition.

The mighty earthworm! A healthy hectare of these has the ability to move 125 tons of soil per year. They are the agents between above ground activity and below ground recycling. Their movements through the soil create air channels for oxygen to flow and for the movement of water. Surface

water flows down into sub soil zones and root systems use these channels to delve down through the soil profile. The function of the worm is to activate the nutrient cycling process. They are potentially the most important creatures on our farms. They eat and move soil around. Vermicasting (worm casts that are defecated by the worm) are five times richer in available nitrogen, seven times richer in available phosphates and 11 times richer in available potash. But it is their ability to neutralise soil pH that is of primary importance. As the ingested soil passes through the worm's gizzard, calcium is added and the subsequent worm cast has a pH 6.4. This general relaxing of soil pH then triggers other macro elements to start to independently function within the soils.

Other invertebrates include arthropods, such as mites and millipedes, which are shredders. Roughly three quarters of all living organism are arthropods. They shred and deconstruct surface litter and organic matter making it easier for bacteria and fungi to further decompose and extract nutrients from this decaying organic material.

I. Exudates

Exudates are the food (energy) that sustains all soil life forms in symbiosis.

The living roots feed these microbial communities in a relationship that is known as symbiosis, where two or more different species work together for the joint goal of survival. The plants need the minerals transported and released by the microbes and the microbes need energy in the form of glucose from the plant exudates. Over millions of years of evolution, they have come to form a partnership. Plants produce plant exudates through photosynthesis, transferring light energy from the sun. CO_2 is sequestered through the plant stomata and then there is a chemical reaction with water from osmosis in the roots that produces carbohydrates. Initially this is for the plant's own use but they can secrete up to 70 per cent of this carbohydrate (also called plant exudates) to feed the microbiology and fungi in the rhizosphere. This is an area immediately around the root fibres where the plants trade carbohydrate (glucose) for minerals and other nutrients provide by fungi and microbes.

J. Plants

Pasture plants bridge the gap between soil, the atmosphere and light. They are commonly harvested (grazed) by herbivores. Building plant biomass is an important part of the holistic system. But it is less complicated than it sounds, because all you really need to do is stand back and allow the botany to express itself. The soil acts a bit like a grazing mirror, so what you see above ground reflects what is happing to the root system beneath. When I was set-stocked grazing and the grass was commonly around 10 cm high, my root systems only went 10 cm down and the roots were only managing to access soil nutrients to this depth. When we changed to rotational grazing practices, and started to increase sward height, the plant roots started to explore further down into the soil profile, opening air channels, storing more energy, feeding more life and finding more minerals.

In a little-known fact, plants control the soil food web for their own benefit. They are able to manipulate the numbers and different kinds of bacterial and fungi attracted to the rhizosphere by the exudates that they produce. These microscopic populations vary over the season depending on the nutritional needs of the plants and the exudates they produce[2].

After several years of rotational grazing, our root depth has increased markedly to 60 cm, and our soils have started to aggregate; at this point the farm is starting to build organic matter and increase topsoil.

Figure 4: Greater root depth and aggregated soil (Source: Author's Farm)

K. Herbivores

Herbivores, cattle and sheep to you and me, eat pasture. Through this Nuffield scholarship, I continually asked why, as an industry, do we set stock. When we look at the natural movement of animals across the planet, they all migrate in large numbers, grazing, trampling and defecating as they move and never returning to the same place until the plants have fully regrown. Is it ease of management or laziness that has created the set stocking system?

With herbivores having more than 1,000 sensory points on their noses, they are adequately equipped to deal with a diversity of sward and mixed nutrient content. It is fascinating to watch animals graze when given a choice. Cows are roughly non-selective and will wade in ripping, chewing and trampling as they go. With tall enough cover, they will graze off the top third of the plant biomass on the first pass over new pasture. Subsequent grazing in a 24 hour period will reduce this further. This is grazing, but grazing is not impact: impact is the density of animals per Ha. The pasture that is not grazed has to be trampled or broken over so that it makes contact with the soil. Invertebrates and bacteria start to recycle this organic matter along with the deposited manure to complete the nutrient process. Sheep do not have the same grazing power or impact as cattle. Nutritionally they also need a higher plane of nutrition. In an average sward of 10.5ME (Metabolic Energy) sheep will selectively grazed an 11.5ME diet in the first 24 hours.

[2] *Lowenfels J., and Lewis W. (2010) Teaming with Microbes Microbes*

Chapter 5: Light and Energy

A. Light as energy

All energy stored as fossil fuels is a derivative of solar energy and all energy currently produced through photosynthesis is a derivative of solar energy today. This is the one true global currency and every life form relies upon it. As a farmer, any sort of farmer, our effectiveness and profitability is our ability to intercept as much light energy as possible. We need to have leaves of every shape and size covering a multitude of heights so that we can intercept as much of this solar energy as possible before it hits the ground. The light energy that is captured through photosynthesis is used by the plant to grow and expand its leaf area with surplus energy from this process then turned into carbohydrates or plant exudates to feed the microorganism in the soil.

B. Pasture diversity

The more diverse we can make our pasture the more stable and resilient our farming system will become. With the introduction of each pastural species we also introduce and empower the biological communities that associate with that particular plant. The more complex and diverse a community becomes, the more stable the population is. In a pastoral sense this applies to plants as well as the associated microbes and fungi living in the soil. Pastoral diversity allows us to grow a very wide variety of plants that can capture light at a multitude of levels. Each of these plants provides different degrees of nutrition as well as has different nutritional needs therefore mobilising a greater range of minerals and nutrients in the soil. The bigger and faster this nutritional cycle, the more carbohydrates are turned over and the greater the amount of carbon that is stored.

C. The carbon churn & respiration

A primary function of pastoral plants is to breath in Carbon Dioxide (CO_2) as part of its day-to-day respiratory process through the Stomata based on the underside of a plant leaf. The energy from light produces a chemical reaction within the plant. This chemical reaction breaks apart and rearranges the molecules, which then turns the water and carbon dioxide into glucose, a simple sugar, which in turn feeds the plant. As the glucose is created, oxygen is created and then dispersed through stomata. The surplus glucose, which can be up to 70 per cent, then feeds the microbiology in the rhizosphere through plant exudates. The more diverse this process the greater the amount of carbon that can be sequestered and the more soil biology that there is to feed. But the name of the game here is to stabilise this sequestered carbon in the soil. Science is not exactly sure how this works at present, but the current thinking is that soil pore space has a lot to do with it. Again, back to the more diverse the pasture, the greater the range of root pore space, the more options there are for the microbes to produce organic compounds which are then absorbed onto soil mineral partials and stored within these pore spaces in the soil.

D. Brixxin' it

In its simplest form Brix is the measure of sugar or glucose in the cell structure of plants. Its range can be over 30 points, but it is generally accepted that when you achieve a Brix value of 18 you have completed the nutrient cycle as denoted by Dr Christine Jones in the Liquid Carbon Pathway[3]. To achieve a high Brix value the biological properties in the soil need to be operating at speed and the plant needs to be photosynthesising at a high rate noting a high degree of carbon churn. Diversity of plants again helps aid this but to what avail? The higher the Brix content of the plant the healthier the

[3] *Dr Christine Jones, The Liquid Carbon Pathway talk at Groundswell in 2017*

underlying ecosystem is. The healthier the plants, the healthier the pasture is for the animals and therefore, the healthier the grazier the better their performance.

Our initial Brix levels were around 6, today we are starting to achieve a Brix of 14.

Chapter 6: Rest and Impact – the Grazing System at Rotmell

Introducing grazing animals to the new system is the next step. How do we produce food from cattle and sheep without upsetting the balance of the functioning components as discussed? In 2012 we started a rotational grazing system on our home farm at Rotmell, based on the New Zealand models. Since then I have observed the outdoor environment and the way my animals respond to that environment, as well as their performance. This chapter is about my mistakes and how I made changes to my system, always striving for the point of balance in the Rotmell system. Maximising utilisation was the initial mantra: I can't afford to waste a blade of grass. Over time residual heights have increased from 1200kg/Dm HA to over 1800kg/Dm Ha. My mantra has changed from 'maximising' to 'optimising' utilisation.

As noted previously, Rotmell is a 992ha farm, with 130 improved ha. There is a lot of land up on the hill that mechanisation (tractors) cannot influence. But this land still has a grazing value. Most upland red meat country in the UK cannot be easily mechanically improved.

Every hectare will grow something; the trick is harvesting the potential of that hectare by mastering rest and impact. The beauty of all these rough Ha is that botanically they are diverse. Historically they have all been over grazed, but when given the chance all the forbs and herbs I would hope to grow in an improved pasture appear naturally up there on the hill. They are not as productive as the bred species of grasses, but they are certainly adapted to their environment.

Impact is a balance between mob size/density, water supply and time. Mob grazing time is a lifestyle choice, some people work to eight-hour shifts, although most are between 24 and 48 hours. The quicker the shift, the greater the impact between pasture grazed and the resulting biomass being trampled into the ground. The bigger you can make the mob the easier it is to manage and the greater the period of rest that can be established. But providing adequate water becomes a challenge. One hundred lactating beef cows have the potential to drink 13,000 litres a day over four periods. This can equate to 3,250 litres an hour and supplying this volume limits the mob size. So, animal impact in as big a mob as possible for as short a period of time utilises over 50 per cent of the available biomass while leaving the rest of the pasture to be trampled into the ground.

What a waste of feed! Or is it?

We have external working partners in this ecosystem management arrangement that we call farming. The trampled plants are not actually waste, but green manure that is the less digestive pastural species that the animals have chosen not to eat. By pushing these plants into the soil, our microbiological partners start to decompose them into the soil, building soil organic matter – this is the living soil. The 'Soil Food Web' is activated and the nutrient cycle started. This surface litter provides other benefits as it also disperses the sun's heat from the soil, as well as holding frosts a bit higher above ground. Surface litter also breaks the impact of rainwater droplets and allows more water to be held on the surface before translocating down through the root systems. In essence, trampling provides a consistent environment by recycling nutrients and protecting the soil microbiome from temperature and hydrology erosion stresses.

Figure 5: Dean Martin & Sam Lang on Dean's farm in New Zealand (Source: Author)

Dean Martin (pictured left with NZ NSch Sam Lang in 2017) was inspirational for managing and understanding soil health; he farms in Napier, North Island, New Zealand.

Dean's annual challenge is managing a lack of consistent and dependable rain fall. Over the last 10 years he has developed a diversity of pastures and fencing systems to allow him to collect as much as the unpredictable rainfall as possible. Maximising the utilisation of pasture is actually not Dean's priority; he uses excess pasture as a tool to slow down water run-off and break rainwater droplet size. Once the grass has grown tall and senesces, Dean said the feed-value to livestock is of little value. After weaning his lambs at around 90 days they are moved onto high quality forage crops leaving the senesced grasses for ewes to wander through in tight mobs grazing out what they can while they trample and brackle over the rest. These trampled grasses then form a layer above the soil which do three things:

1. They reflect the heat of the sun, keeping the soil cooler and reducing evaporation.

2. They trap a layer of CO_2 which can be easily inhaled by the stomata of the plant.

3. They act as a deflector or diffuser of rain droplets. This reduces the impact of rainwater droplets hitting the soil and reduces microscopic soil erosion. In a dry environment this is imperative as the water slows down. Slow moving water has a chance to soften soil and soak into the soil profile, through worm holes or running down plant roots. The greater the root depth of plants, the deeper the moisture can penetrate the soil profile.

It is understandable why this is so important in dry, arid climate but you would think not so important in the UK. Slowing down rain droplets on impact is more important here than we might think. We get more rain and it's starting to get more unpredictable, so there is a greater potential to leach more nutrients and increase erosion. Management at soil level can provide the water with a place to go that is not flooding, erosion or leaching. Allowing this resource to run off the soil and escape down a ditch is not the ideal solution; in fact, increasing the absorption of water into the soil will reduce the impact of flooding which is a growing weather threat and cost in the UK.

While we strive to maximise impact with our cattle grazing, we cannot do this with our sheep flock as easily. These ladies need sweet feed 24/7 and choice is the order of the day. The smaller the animal the more sensitive the rumen to the quality of feed offered. On a high-lignin diet the rumen function of cattle slows down, so this gives time for the animal to absorb nutrients more effectively; sheep perform better on pastures that have had a shorter rest period (i.e. the pasture has younger growth). Our rest periods between sheep grazing varies between 18 and 40 days over the grazing season. We are trying to make sure that the sheep are offered lush pasture with limited seed heads and a high diversity of legume and herbs. They are permitted to eat less than 50 per cent of the

available feed and are then moved on, leaving a rest period for pasture recovery that perfectly suits cattle about 21 days later. My experience proves that when sheep are asked to graze to a set residual of 1400DM/ha you have pushed their grazing too far. Their preferred grazing choice is gone and they enter nutritional stress. As pasture quality falls, animal feed intake drops and they enter the parasite zone, by which I mean that nutritional stress makes the animal vulnerable to parasite attack. By introducing cattle to the pasture after the sheep, which is simply herbivore diversity, we are introducing different grazing patterns and breaking the parasite cycle. Cattle will eat what sheep leave behind and vice versa.

Rest is essentially a period without grazing where you give time for the plant to recover and the system to rebalance. Sometimes I target quality leaf growth to meet the animal's nutritional requirements. Also, I may allow enough rest for the plants to senesce and reseed, to improve the diversity of age in the pasture. However, plant diversity also makes the rest response difficult to manage as each species of plant grows at different rates. If I want to increase photosynthesis and the energy flow, a plant needs rest to regrow and increase plant mass. This makes the rest period complicated, but nonetheless an essential management tool to building and maintaining the balance of plants, and how my herbivores interact and perform within the system.

A. Parasites

When things go wrong, or what you may perceive to be wrong, it is generally just an indicator of imbalance in the system.

I spoke with Dr Keith Ballingall of the Moredon Research Institute near Edinburgh about genetic interaction to resistance and immune response to herbivore parasites.

How does genetic selection react to resilience? Or is it resistance we should be trying to select for? If we are breeding for resistance, where is the limit before this resistance drops?

Dr Ballingall made me realise that genetic diversity is resilience. Genetic diversity applies not just to animals, but to plants, and microorganisms. A parasite or a perceived pest comes about because diversity is lost in the environment. The more diverse the system the more resilient it is.

Selecting genetics for any specific traits leads to a monoculture. If we push genetic selection too far away from diverse traits or breed pure, we are breeding a herd or flock that is in essence a monoculture. It is true that nutrition drives everything when in balance. But loading a farming environment with only one species allows an imbalance to be created. Parasites will always be in the environment, but genetic diversity will not permit them to become a monoculture.

Dr Ballingall concluded our conversation with some striking comments that have stuck with me: ***"There is no case to promote maximisation of Live Weight Gain. In doing so we are continually selecting for failure,"*** and ***"'OPTIMISATION' is not a phrase often used in relation to red meat agriculture. But selecting for moving the average rather than making the perceived best better, is a more resilient approach."***

Conventional thinking promotes a continual maximisation - how fast can we make it grow; how much can I grow. But this is actually leading down the path to monoculture where we are continually selecting for failure. In a diverse system we want as many traits as possible to give resilience to all the component parts of the system. In a diverse system we reduce the need of anthelmintic because we give the animal the nutritional support and choice to avoid the parasitic threat.

"LESS DIVERSITY IS BAD: Any selection you do reduces diversity and resilience." Dr Keith Ballingall

B. Rumination of Red Meat

Soil microbiology and Rumen microbiology are directly linked. The biology or biota of a cow pat contains the same microbiology as is in the soil.

Dr Robert Hungate, a zoologist became the leader in ruminal microbiology, thus earning the title of the father of rumen microbiology recognized that the rumen is a continuous culture system. The following is his description of the ruminant animal: "a small fermentation unit which gathers the raw material, transfers it to the fermentation chamber, and regulates its further passage, continuously absorbs the fermentation products, and transforms them into a few valuable substances such as meat and milk"

Within the rumen there is a direct relationship with the microbiome or the ecology that is known of the rumen, coupled with the density and diversity of bacterial, archaeal, protozoal, and fungal populations. These very same bacterial and fungal populations are found within the living entity of the soil, otherwise known as soil microbiome.

When stripped back to the logical point, it is completely sensible that these microbial populations that recycle nutrient within the soil are the very same population that aid rumen function and digestion within our humble livestock. Evolution is again providing a mutualistic relationship to complement nutrient and energy recycling.

C. Selecting genetics for failure

Genetics and the environment: The expression of an animal's genetic potential can only be expressed if it can be fed well. In any environment there is a trade-off between Genotype and Phenotype. This was never explained to me better than by Dr Ann McLaren and Dr Nicola Lamb at Scottish Rural Collage (SRUC) major research farm, Kirkton, in the West Highlands.

Phenotype is the animal's ability to handle the environment and Genotype dictates the level of the performance, but it is the management pressure that is applied in the farm system that dictated the outcome of both. The value of managing with Estimated Breeding Value's (EBV) is that they take away the variability of the genetic performance while also highlighting which phenotypes can thrive in the environment. That's why the maternal EBVs have such low heritability, because most of what happens is down to management and managing these variables without the use of EBV becomes impossible. But there is a small part that is genetic, and because maternal genetics are eight times more valuable than terminal genetics that is why maternal EBVs (despite low heritability) are calculated. Buying the best maternal tup in the world won't necessarily give you instant improvement in maternal characteristics if your management is poor. But that's not a reason not to invest in good maternal genetics. They are permanent and accumulative.

Prof Kathy Dwyer of SRUC continues this theme around phenotype. Getting ewes to a Body Condition Score (BCS) of three has the single greatest influence on lamb survival and performance. Her subsequent work proves that a lamb has to suck 50ml of colostrum in the first two hours of life or it has a 50 per cent chance of dying in the first 100 days. The vast majority of neonatal deaths are due to the lack of colostrum and subsequent death is because there was not enough passive transfer of immyoglobin at birth to help stop bad bacteria developing in the gut. The fascinating fact about

this is that lamb vigour to suck is not a direct reflection of the ewe's maternal behaviour but is more directly linked to the vigour of the sire. How often have we seen a dopey tup lamb that is helped to suck and heard 'Aye, but it'll win the local show!'

One of the most surprising uplifts at Rotmell came in the sheep flock. As we increased fencing infrastructure and could control quality and quantity of the pasture better, our scanning result climbed from an historical average of 130 per cent to 150 per cent and lamb mortality dropped to less than 10 per cent from scanning to docking. Managing a sheep flock to BCS3 worked!

Figure 6: Rotmell Farm, subdivision allows more precise management of nutrition (Source: Author)

This was again hammered home when listing further research by Meat and Lamb Australian at the EAAP conference in Belfast. Dr Forbes Brian from the University of Adelaide has studied the genetic approach to improve lamb survival. His conclusion was that the greatest effect on lifting lamb survival was to increases Body Condition Score to above three pre-lambing. This would increase lamb survival by 6 per cent in single and 14 per cent in twins.

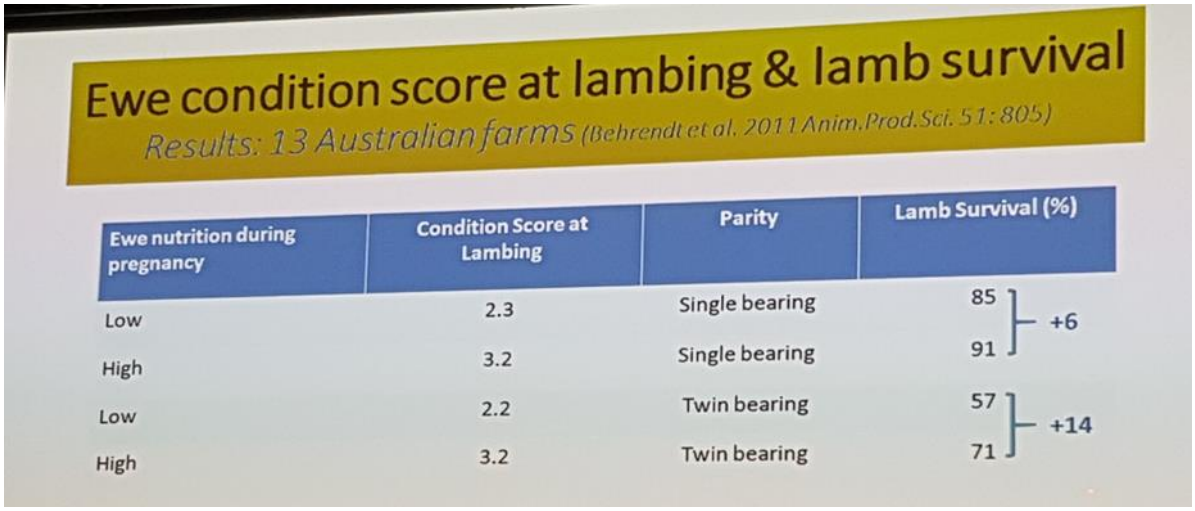

Figure 7: Lifting BCS to increase lamb survival (Source: EAAP Conference, Belfast Dr Forbes Brian)

Chapter 7: Empowering Consumers

A. Headwaters, New Zealand

While traveling through New Zealand I was fortunate to get the chance to interview a sheep breeding group called Headwaters in Wanaka to find out about the Te-Mana Lamb Project.

In 2006, 17 farmers and professional service providers to the sector established a new livestock business venture called Headwaters. Headwaters is based on an agreed culture between everybody bought in, even the lawyers and accountants. All participants were involved on a share basis, with one share per ewe, and every ewe valued at $1. New members must sign a contract to supply lamb and in return they gain the benefits of a guaranteed market as well as the genetic gain to their flock. The Headwaters group has grown to around 60 producers with all members sharing in the intellectual property.

Headwaters was an initiative driven by determined breeders who wanted to stand on their own two feet and not blame anyone else for failings in the sheep industry. The aim was to establish breed characteristics which would give them control of the breed phenotype. By controlling the genetics, they could control the supply chain.

Headwaters producers wanted to create a composite ewe which is fit for high country. They selected a diverse gene pool from Texel, Romney, Finn, and Perendale (half Cheviot, half Romney) breeds. The first action of Headwaters was to set out the breeding objective. Genetic diversity was a key trait they bred for. This unique breeding programme has resulted in a sheep that has developed a metabolism suited to upland conditions. The breeding targets are tough. They aim for 150 per cent weaned lambs to the number of ewes mated. Finn sheep have high fecundity and fertility, with good milk and high solids. They have finer wool, and intramuscular fat (IMF) distribution. The Finn can maintain better performance in a hard year; they will carry more lambs with more resilience. The New Zealand Texel is tough, yet more maternal but has been culled hard for faults in feet and wool. The Romney is known as the oldest proven sheep breed and many farmers are happy with them.

The thrust of the business was to be in control of the maternal genetics by producing and owning a composite sheep. Through Headwaters development work IMF were found to be a great energy resource in the breeding flock. Further work here discovered that IMF are high in Omega 3, which is a polyunsaturated fat and good for heart disorders as well as adding to the flavour and tenderness of the lamb. This then became the unique selling point and creation for the “Te Mana Lamb brand” and a significant 34 per cent uplift above conventional lamb price.

B. New Zealand – the Te Mana lamb project

Figure 8: This Te-Manu lamb is the greatest piece of lamb the author has ever eaten! (Source: Author)

The New Zealand Department of Primary Industries co-funded the branding and marketing establishment as well as some of the genome work. The next stage is to breed the perfect tup for the Headwaters system. While tups are the entry point to the system and the number of ewes in the programme means that sire genes need to be consistent. Individual gene markers are the future for Headwaters, so they are not interested in terminal sires as such. Progeny testing 400-500 tups is planned, so that DNA for specific traits like loin or Omega 3 can be bred to protect the brand. Scanning meat traits like size of loin or IMF depth at the farm is a refined selection tool, making it easier to choose animals for quality.

The Te Mana brand is not just about the meat, it is a farm system. Athe Headwaters farmers follow the same finishing procedures.

	Period	**Diet**	**Target weight**
To weaning	90 days on mum	300g/day	30kg
Finishing	35 days on chicory	270g/day	39.45kg

Alliance Distribution Group are mostly working with frozen product now. Product development has shown that the high unsaturated fats protect the quality of the meat. Freezing followed by gentle thawing does not deteriorate the meat quality. This means a significant volume of lambs are

slaughtered at their best and the product can be processed to add value. There is also the benefit of added transport time to distance markets without deterioration of meat quality. It means that Te Mana is not a seasonal product like other lamb produced in the world but can be presented to the market on day of the year.

What is evident from the Headwaters project is that collaboration and drive can revolutionise a supply chain. Clearly defined roles (Headwaters is breeder and lamb provider and Alliance process and market the product) mean that there is a smooth flow of product to the consumer. There are few hiccups and expert knowledge is shared. Owning the genetics and retaining farmer buy-in means the group can stay ahead of trends while continually meeting demand for a bespoke product. As the farmers have signed up to the product, they all follow the same system. A member of Headwater may own 1,000 ewes, but they are part of a wider group that is selling hundreds of thousands of lambs. Quite a significant strength.

By applying focus to genetic diversity and breeding, by taking charge of one's destiny and grabbing opportunity, a maternal robustness has been created as well as value and health placed into a lamb product.

Is this not the question we should be presenting to the UK sheep Industry?

C. European Animal Science Conference, Belfast

In Belfast, I met an American cattle breeder. The American meat grading system is based on marbling and cattlemen focus on meat tenderness, as the product is all about the eating experience for the consumer. They start with the right breeds and Aberdeen Angus is a favourite as it has good muscle and tenderness, if the diet is correct. Subcutaneous fat is required to reduce meat shortening and they don't want the connective tissues that go tough. Younger animals have less connective tissue (also called silver skin) so they are looking for muscle-dense animals to produce a tender meat. As marbling goes up, sheer test (toughness) is less, but flavour and taste improve. All the techniques are focussed on bringing tasty and tender meat to the consumer. But the economics are not ignored either. There are cohesive links in the supply chain with everybody understanding the upstreaming and down streaming elements of the market system because after a bad eating experience there may be a minimum of three months before some people try the produce again.

Figure 9: IMF, enhancing eating quality. (Source: Author)

Chapter 8: Creating the wow factor

A. INAC, the Uruguayan National Meat Institute

As I travelled through Uruguay the sky seemed to run on forever over gentle rolling hills; this is a country with a proud tradition in beef. Since the 1600 century when the Portuguese arrived into South America, beef has been a major export.

Figure 10: Uruguay Gaucho, raising beef with confidence. (Source: Author)

To repeat a quote from INAC which has never seemed more apt: "*We don't have to sell meat, we need to sell confidence.*" This was the thought process after the Uruguayan meat industry was wiped out with foot and mouth (FMD) back in April 2001. Foot and mouth decimated the country's economy. With three million people and 12 million cattle, red meat is the most important export product for Uruguay, with more than 300,000 tonnes of beef exported in 2018[4]. After the FMD national disaster, rebuilding the beef industry was of national importance for the country economy but also for its self-belief and national pride. Uruguay per capita has the equivalent income per person as Germany or the UK. It is a wealthy nation with an outward-looking perspective. It was the economic as well as the emotional ties that drove the rebuilding of their Red Meat brand.

INAC were quick to identify opportunity when rebuilding: Everybody tries to sell grass fed. But what is grass fed? INAC recognised that the origin of the product is important for the consumer. With

[4] INAC, Statistical Report Year Ending June 2018, p44

these mantras the focus was to use "*humour with a positive message, we sell confidence; we work with certification and use this to create the brand.*" This industry image and branding wins global meat awards and recognition. With this dedicated approach global red meat markets re-opened and within four years of the FMD crisis the Uruguayans have grown their global meat sale 12 per cent above pre-FMD levels.

INAC marketing is very consumer-focused, extending past the importers and directly targeting the consumer with image and messages. The brand messaging features alluring countryside vistas with green grass, distant hills and rippling rivers. The messaging allies nature with meat and chimes an emotional response. This was an important factor in opening lucrative markets in Russia (exports have grown three-fold since 2016[5]) and China (beef exports are worth USD 651 million[6]).

"If you want the image of sun and grass on your plate it takes time to grow so take the time to enjoy it." *Silvana Bonsignore, Marketing Manager INAC*

To prove the provenance of their meat brand INAC then developed a certification system which gave them proof of product to their demanding markets. The Uruguayan meat certification scheme applies to all parts of the meat production process and gives control over animal welfare, food safety and ultimately illustrates a quality product that is fully traceable. Although the farmers are somewhat reluctant, the certification scheme requires the use two tags (one EID). The use of EID tags and QR codes demonstrates traceability. INAC is convinced the **farmer** must stand up and be proud of what they produce – the authenticity of the honest face is an important part of the meat chain from gate to plate.

In response to near total industry failure, INAC has gone out to sell meals with "*a history, a provenance and close ties to the environment*". The certification scheme means they can sell to a specific standard. It enables environmental as well as quality credentials to be demonstrated to their global customers.

Their moto behind the scene is "*Beef as good as Scotch*".

B. Allan Savory and 3LM

After a very convoluted process exploring land management practices around the world, I finally discovered Allan Savory and Holistic Land Management.

Everything fell into place as soon as I interviewed Christopher and Sheila Cooke of 3LM in Cumbria (a member of the Savory network) in 2017. I still had so many questions, in fact more questions than when I started my Nuffield Scholarship, and it was 3LM who started to make sense of everything I had learnt so far.

We talked about Holistic Management and Ecosystem Services, and these conversations brought me to challenge myself: as a farmer what am I really managing for? What outcome do I want?

Allan Savory said that nature is so complex we may never fully understand it. Following this thread I explored Jan Smut's Theory of Holism (1926) where he states that scientific research has divided itself into compartments – biology, chemistry, geology, hydrology etc. Jan Smuts saw that matter, life and mind should not be seen as separate domains, but rather as an integrated whole.

[5] *INAC, Statistical Report Year Ending June 2018, p42*
[6] *INAC, Statistical Report Year Ending June 2018, p49*

Allan Savory says that change can become normal and to remain stationery is often an abnormal state. Modern soil scientists talk about soil imbalances but in holistic management, imbalance is not a big topic. Holistic management corrects imbalances by providing time, so the emphasis is on managing the key parts together to strive for balance and, by putting the right conditions in place, a natural balance will be achieved.

Holistic management is about managing the whole. Allan Savory described working with ecosystem processes. How the water cycle ties into the mineral cycle. Gathering moisture and holding it on the land by trampling and creating green manure, this also allows the decaying biomass to make contact with the soil microbiology which recycles these nutrients and moisture to translocate down through the soil pores. The energy cycle is generated by capturing as much solar energy as possible, this powers all these systems and then community dynamics provide the living organisms that enrich and drive this exchange around holism.

These are the four ecosystem processes, but it is the four key insights that cover the effectiveness of these systems. The first insight is that nature works in wholes. "Individual parts do not exist in nature, only wholes and these form and shape each other," says Allan Savory. The second key insight is the brittleness scale and lands reaction to water. We are fortunate in the UK to farm in a maritime environment and this enables us to rest land for shorter periods of time as moisture drives pasture recovery. Insights three and four are tied together around animal impact and numbers. As livestock graze and move they trample surplus pasture into the ground, therefore having the effect of creating plant soil contact by treading in the manure, urine and old plant matter, and their density of numbers for short periods helps create a herd effect, so mimicking nature.

From these conversations I have come to the realisation that in our generation we will probably not fully understand how the soil and the life within it really works, and as farmers we probably don't really need to know these intimate interactions. We do, however, need to appreciate that something as yet not fully understood is happening beneath our feet. Our job is to try and manage the interaction between light, moisture and heat and how that is absorbed into the soil biome. Then we have to recycle that energy through pasture into the livestock that we grow and then sell.

Chapter 9: Conclusions

A farmer by definition is somebody who cultivates land or raises livestock.

Regardless of what type of farming system we wish to put in place, billions of years of evolution has generated a biological system that works. If we continually try to throw technology and chemistry at a biological process it will eventually break. Farming is a gentle business that relies upon biological diversity to build resilience. It is an environment of ecosystems, seasons and cycles, with no individual element more important that the other.

As a new Nuffield Scholar, we were briefed with the task of "Making farming sexy". I haven't done that, but what could be more current than realising through this journey that the land that I farm has all these biological process within it that will allow us to manage the greatest challenges facing humanity today, global warming.

I love it when people tell me my beef tastes fantastic. However, consumers are being pushed into a place where emotionally it is controversial in today's climate to buy red meat. This is not only a threat to pastoral farming, but a far bigger issue to the global environment. Red meat herbivores are essential tools in the way we sequester carbon, manage water, and provide a diverse environment. Red meat production is not part of the problem, but part of an environmental solution.

Building Soil Organic Matter through diversity allows the land to sequestrate and store CO_2 at depth whilst releasing oxygen back through the plants' stomata to the air. This happens by stabilising and storing water and creating energy flow through photosynthesis. The motor behind all this positive exchange, are herbivores, if managed properly!

Herbivores convert solar energy into nutritious red meat. They are the key component of this recycling process, which ends up with the smallest of microbes resetting this nutrient cycle again. As a land user, agriculture has a responsibility to manage the land in a way that delivers public good and environmental service. You could say farming is a contract with society to provide food and wellbeing and other public benefits. When the consumer buys a steak, they take a stake in the restoration of land, water, air quality and carbon sequestration.

The relevance of red meat in the 21st century has never been greater. Herbivores are the primary animals in land restoration and ecosystem services through the completion of the nutrient cycle.

Chapter 10: Recommendations

I have never mentioned subsidised agriculture throughout my report and nor do I wish to. But arguably it has created an inward and introvert industry which has not fully realised the potential it has to positively contribute to our global challenges: land quality; water quality; air quality. More often than not, primary production is far removed from the family home of consumption. The message around total nutrition of land, livestock, environment and human health has been lost around a mire of capitalism and globalisation.

My report sets out to explains the importance of soil and grass knowledge to develop a profitable and sustainable business by optimising genetic and pastoral efficiency. I would recommend all Farmers give more focus towards ecosystem management. Pastoral lands are the world's lungs with the potential to absorb and stabilise twice as much CO2 as the world's forests.

I recommend the following on-farm KPIs that can be aspired to:

1. From the bottom to the top encourage **Diversity**, it leads to greater:
    - **Resilience**, buy buffering the land and genetics from climatically extremes;
    - Build **Soil Organic Matter** through greater root depth, increased photosynthetic capacity of plants and holistic timing of grazing impact and pastoral rest;
    - Build and **sequester Atmospheric Carbon** into **soils, plants, herbivores and meat**; and
    - Create a positive engagement around food production and ecosystem services.
2. Although, Farmers, Land managers, Civil Servants and Politicians must realise that optimisation is not an excuse to be technically or productively sloppy, but the realisation that maximisation in whichever direction is heading towards monoculture and ultimately failure.

Chapter 11: After my study tour

We are continuing to build on this extensive bank of knowledge that has been learned over the course of my Nuffield Scholarship. On the ground, our grazing platform is evolving into a diverse array of plants and we are feeling our way through ever-changing grazing strategies.

We are also building marketing capacity with a joint venture partner to sell more red meat direct off farm.

- I am very mindful of the change in me; individual KPIs are less relevant than they used to be as I take more time to examine the whole. Ecosystem process is a very large part of my day-to-day thinking as I consider the total nutritional health of my farm and livestock.

- There is a great image and truthful story to be told about the holistic value of red meat farming and its collective value to society in the 21st century.

- The balance of livestock has changed at Rotmell with sheep number reduced as we look to create a composite flock that is more resilient and productive. The limit with the sheep flock is our ability to provide high quality nutrition 24/7 on our current land type.

- Cow numbers have doubled to 200 breeding cows as this herd provides the impact that we need to increase nutrient cycling and build biological population within our soils. As fencing and water infrastructure increase our ability to manage time has also increases. With this the nature of the pasture and land changes to a more productive state.

- The future of red meat is green!

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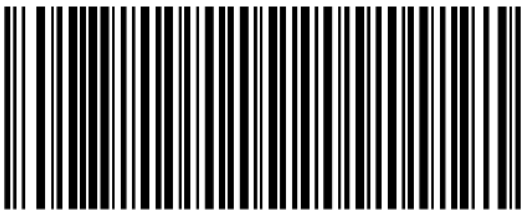
Alex Brewster

Mulder Chart
https://www.google.com/search?q=mulder%27s+chart+of+nutrient+interaction&sxsrf=ACYBGNQBHCHTFTm6Bzg-DCcaYxb9iG_fqw:1582122730234&tbm=isch&source=iu&ictx=1&fir=FQJE2GUk2DHtzM%253A%252CGp2i0OXXSxQXjM%252C_&vet=1&usg=AI4_-kQzmO8RHPguROfDlLoFn0Q-o9gHTQ&sa=X&ved=2ahUKEwiujM666t3nAhVL3qQKHSH8At4Q_h0wAXoECAoQBg#imgrc=Zw1g_g05jX6GtM

Soil Food Web
https://en.wikipedia.org/wiki/Soil_food_web#/media/File:Soil_food_webUSDA.jpg



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