A Nuffield Farming Scholarships Trust Report

Award sponsored by

The John Longwill Agricultural Scheme

Sustainable Milk Production: the vital role of Soil for Feed Integrity

Wil Armitage

October 2014

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A Nuffield (UK) Farming Scholarships Trust Report

Date of report: October 2014

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

Title	Sustainable Milk Production: the vital role of Soil for Feed Integrity
Scholar	Wil Armitage
Sponsor	The John Longwill Agricultural Scheme
Objectives of Study Tour	To identify how leading dairy farmers round the world, regardless of system, were addressing feed integrity. To increase dry matter yields/ha through excellent soil and crop management To identify the pros and cons of First Generation GM technology for the livestock farmer
Countries Visited	Canada Denmark Sweden France USA Australia New Zealand

Findings

- The management of our soil is fundamental in the production of quality food
- High biological soils will produce high integrity feed
- Plant diversity increases forage quality and builds resilience in our soils and farming systems
- The over-use of chemicals in some sectors agriculture is destroying the vital links and synergies between the soil, soil biology and the plants being grown
- 1st generation GM technology can compromise the integrity of the food produced
- Biological farming is highly productive and must be embraced in the future

  (Definition of biological farming: maximising soil biology to produce strong, healthy plants with high integrity, plus use as little chemical as possible and only as required).

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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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1.0. Introduction

Me, Will Armitage

I was brought up on an Exmoor beef and sheep hill farm always knowing I wanted to be involved in agriculture, and after leaving school went to Cannington College and took an NDA in general agriculture.

My parents always said there was more money in dairy cows and I think that was why I started my career in dairy farming. At my first job on Dartmoor I had the opportunity to show cows and heifers and it was at this trigger point I decided I would try to be the best showman in the world; my desire and passion helped me become All Britain Champion Showman in 1988; All Canadian Jersey Showman in 1987; and won the Showmanship class at the World Dairy Expo in Madison, Wisconsin, USA.

As a result of this success in 1990, Peter Dixon Smith offered me the position of herd manager on a new dairy unit where I was promoted to farm manager. We then took the RABDF Gold Cup in 1996 and 1997 and had a show team that we took to the national shows and competed successfully. This was a high input/output pedigree herd milked three times a day – a lot of work but really enjoyable. In 2000 our herd average was 12,000 litres with a cell count of 93. Our best cow was High Point Chief Mary that gave 176 tonnes of milk.

On the back of the success we had with the herd, I managed to secure sponsorship to go rally driving in my spare time from 1996-2000, and competed in the Network Q Rally of Great Britain in 1998 and 2000.

In 2003 Peter Dixon-Smith and I sold the pedigree Lyons herd and then set up a partnership, re-stocked with commercial cows, subsequently converting the farm to organic in 2005, purely due to the financial returns we felt we could achieve. This was quite a shock both to the farm and my management skills but after the initial conversion period of two years the soils have improved year on year; and the business has grown to the point of our buying a farm together in 2011 and now putting in a dairy unit on that farm. More recently we have set up an FBT with an arable farmer next door and are converting his land to organic for our grazing platform, taking our total to 1,145 acres.

I also contract farm a conventional 300-cow grazing herd.

As you can see, during my working career I have experienced some different systems but, regardless of the system, I am a passionate dairy farmer, keen to promote my industry.

I am married to Michaela and have two children: Jessica and Giles.

2.0. My study tour: where I went and why

I should like to set out where it was that I travelled, and why I chose those particular countries:

Country	**Date**	***Reason for choosing this country***
Denmark	June 2013	*Same latitude and a similar climate to the UK for growing crops. Also they have Scandinavian Red cows and I'm using those genetics in my own herd.*
Sweden	June 2013	*60% of their dairy farmers in the Stockholm area have gone out of business over the last 18 months because they'd bought too much technology to save labour – and now couldn't meet the payments.*
France	July 2013	*Joined a trip to study lucerne – which I grow myself*
Australia	November 2013	*Wanted to see Terry Hehir who'd attended the CSC in his capacity as Chair of Nuffield Australia – and who'd inspired me*
New Zealand	December 2013	*New Zealand is the dairy capital of the world! Who could study milk production without going there?*
USA	March 2014	*Went to see Organic Valley in Wisconsin, and then on to Iowa and Minnesota to see, in particular, Biologial Farming.*

When I think back on my travels there are individuals who stand out in my mind as excellent operators or passionate experts within certain areas, and some whom I felt had achieved the ultimate in sustainable agriculture.

It would be impossible to mention all whom I visited or had a meeting with on my travels but I can't think of one that didn't have a positive message or detail that I could take away.

Firstly I wanted to establish what are the factors that make a dairy farming system sustainable.

The quality of the feed being fed on farms in general varies greatly, so I started to investigate what the best farmers were doing to improve this. I found they were all caring for and nurturing their soils and, as a result, were producing top quality feed and forage. This caring and nurturing of soils was the definitive finding of my intensive 9-week study tour and the direction I pursued.

> *The best farmers … were all caring for and nurturing their soils and, as a result, were producing top quality feed and forage. This caring and nurturing of soils was the definitive finding of my study tour*

3.0. The importance of milk

Humans evolved in the Ice Age and animal fats were the major factor in the brain's development and the reason why we are who we are today. Gorillas carried on eating seeds and vegetation and so remained as they were.

To hunt and kill on a regular basis was, and is, not sustainable and, as a result, humans soon found the only renewable animal fat available was milk and so the cow became sacred in many parts of the world due to the valuable contribution she makes to communities.

Since the milk lakes and butter mountains of the 1980s milk has received unfounded bad press, but finally we are seeing some solid research with good evidence showing that greater consumption of dairy improves health in humans, including reduced relative risk of Cardio Vascular Disease. Work at Reading University has shown that men consuming larger amounts of milk have a lower body mass index and reduced blood pressure and men consuming more dairy products had less arterial stiffness.

Milk should be a vital part of a well balanced diet and recognised as the Superfood that it is.

The Cow

The cow is an animal able to convert hemicellulose into a vital nutrient for brain development and function, with the biological waste returned to the earth as the most valued natural fertiliser.

Over thousands of years hundreds of milk production systems have evolved and been adopted to feed a family, make a living, or develop large businesses producing milk.

****

The personal problem that I wanted my Nuffield Farming study to solve

As a passionate dairy farmer, fully bought into the principles above, my personal conundrum was:

> On our organic farm we are currently running at about 70% of the farm's potential organic output; and on the conventional farm we use too much purchased N.
>
> This posed the question: where is the balance and how do we achieve optimum production and sustainability on both units?

I was ultimately to find out that the answer lay in Soil.

4.0. Sustainable milk production

On my Nuffield Farming study around the world, it was very evident that good, successful operators can adopt very different systems: from highly intensive automated robotic 12,000 litre herds; to extensive grazing systems with very little capital cost; and small family farms. These systems - and lots of variations in between - can produce quality milk with very high welfare standards for the cows and a good living for the people involved.

However, the higher the cost base in the system, the greater the exposure it has to financial risk.

From past and present experience, I am happy to embrace all dairy systems; basically it just means a different set of rules and, as the intensity of the system increases, so more rules and protocols have to be put in place.

- **But a dairy system is only sustainable if it is making money.**
- **In all systems there are many variables that affect the bottom line but one has a massive impact on profitability: and that is the quality and integrity of the feed we make available to our cows.**

The cow being a ruminant should rely on 75% of her nutrient being supplied from microbes produced in the rumen.

If we feed her too much rumen by-pass nutrient which goes straight to the small intestine; or if we give her poor quality feed, we affect the cow's production, health and immune system resulting in susceptibility to disease, infertility and short herd life.

It is vital that the quality and integrity of the feed for our cows is high: to ensure that her health, fertility and longevity are good.

We should not feed Empty Calories.

Healthy, happy cows

On my study around the world to establish common factors of successful dairy businesses it became apparent that my visual assessment of both the land and the cows was the best indicator and, where I saw healthy, fertile cows with shining coats, the farmers were very focused on their soil and crop management, and the look of the cow was a result of how these farmers managed their crops in their fields and ultimately their soil.

… where farmers were addressing the calcium:magnesium ratio and other minerals in their soil, their cows looked much fitter

I had identified these links in Denmark, Sweden and France. But it wasn't until I got to Australia and New Zealand - where they are working with high magnesium soils - that I realised that, where the farmers were addressing the calcium:magnesium ratio and other minerals in their soil, their cows looked much fitter than those where such attention was not being paid.

It was Dr. Phyllis Titchin, a Biological Farming Consultant and General Manager of True Health in Hawkes Bay, who really focused my mind on the direction my study should be taking. As a result my report's focus is on soil and the vital role soil biology has in the mineral transfer from the soil, to plants, to cows; and the benefits in productivity and health of all three, and ultimately the impact on human health.

If energy and protein is supplied without minerals - the "building blocks of life" - to any plant or animal, empty calories are fed and a weak structure is formed. Growth may appear to be maintained but the quality of that growth will be poor and result in susceptibility to malfunction and disease.

We cannot feed either cows or the world's population on Empty Calories.

We measure livestock feed quality with NIR spectoscopy which is a very blunt instrument for measuring both energy and protein; and it is a guess, at best, but most livestock rations are formulated on this basis.

4.1. Metabolisable Energy

Metabolisable energy is defined as the part of the Gross Energy value which is:

"the net energy available to an animal after the utilisation of some energy in the processes of digestion and absorption, and the loss of some of the material as being undigested or indigestible".

The customary method employed to determine the ME of feed for ruminants is NIR Spectroscopy, which utilises reflected/absorbed light from the IR spectrum to evaluate the sample against a benchmark, which depends upon frequent re-calibration.

Whereas many feeds, with high dry matter and very few anti-nutritive factors, can be reasonably accurately verified in this manner, the problems arise with grass/maize/whole-crop silages, particularly wet grass silages, as the NIR methodology is not covering qualitative differences in fibres, carbohydrates, and the many significant anti-nutritive components potentially found in silage (such as unpalatable acids, rumen pH depression, amines, etc.)

> For instance, a farm with cows averaging around 25 litres per day, feeding a known concentrate fraction, may receive a silage analysis with a dry matter of 25% and a predicted ME content of 11.5 Mj/Kg.
>
> That farm is feeding the average cow:
>
> 6 Kgs parlour feed (19% CP, ME 12.5) 6 x 90% DM x 12.5 = 67.5 Mj
> 6 Kgs brewers grains (22% CP, ME 11.7) 6 x 22% DM x 11.7 = 15.44 Mj
> 2 Kgs SBP (10% CP, ME 12.5) 2 x 90% DM x 12.5 = 22.5 Mj
> That totals: 67.5+55.44+22.5= 105.4 Mj
>
> Milk output is 25 litres, so the daily ME requirement per cow is (Maintenance 68 Mj) plus 25 x 5.2 Mj (requirement per litre) = 68 + (25 x 5.2) = 198 Mj.
>
> Subtract concentrate contribution from required intake (198-105.4) and the silage contribution is 92.6 Mj. Evaluate silage intake via weigh cells: for instance, 42 Kgs: giving a silage DM intake of 10.5 Kgs, and the net result is that silage is yielding a true value ME of 8.8 Mj/Kg.

The difference will vary dramatically from farm to farm***, as it is the factors that we do not analyse which have the largest effect on the availability of the energy fraction.***

As a dietary advisory tool, it could even be argued that conventional NIR analysis is counter-productive, due to its tendency to overvalue the like contribution of a significant proportion of the silages submitted, hence creating a ration formulation bias which, by its very nature, underestimates the requirement for energy to meet genetic potential.

Protein

NIR spectroscopy predicts crude protein content via the same IR absorption/reflection technology as described earlier. It is based on absorption of NIR energy at specific wavelengths by peptide linkages between amino acids of protein molecules and at reference wavelengths. So although the evaluation may be reasonably accurate in giving a total crude protein percentage, in ruminant nutrition the form and availability of the protein is what determines the productivity.

> *… in ruminant nutrition the form and availability of the protein is what determines the productivity.*

Much UK silage is made in poor weather conditions, and fermentation pathways are often unpredictable; as proteolytic micro-organisms such as clostridia can deaminate protein, creating potentially toxic by-products such as amines (histamine, cadaverine, putresine etc.) and amides. The real value of silage protein is hugely variable, with anti-nutritive factors frequently ignored by conventional analysis.

In addition, the nutritional requirements of the ruminant in terms of essential limiting amino acids are a relatively known quantity. However, for the growth and maintenance of healthy rumen microflora, NH3 supply may be adequate but, without the requirements for amino acids that are not synthesised by the rumen micro-organisms - such as methionine, lysine, leucine, threonine, etc. - then the diet, regardless of the analytical CP%, may well be productivity-limited.

The real value of silage protein is hugely variable, with anti-nutritive factors frequently ignored by conventional analysis.

The rumen microflora (particularly protozoa) are intensely pH sensitive, so both CP utilisation and energy availability are impacted to a large degree by rumen pH and, in the case of rapidly fermentable diets, it's not unusual to see dramatic pH falls in cows, leading to acidotic or sub-acute acidotic conditions.

Silages that are very high in lactic acid content, highly soluble, and which by their very nature are more susceptible to yeast/mould aerobic instability, will probably analyse with high predicted values, but dramatically underperform. Whereas silages which may be determined to be of lower ME and CP by analysis, but possess higher DM content, more fibrous carbohydrate, and lower acid levels, could be far more "rumen friendly"; hence more likely to encourage salivation and rumen health.

Mineral analyses tend to be pretty accurate but how these are used to formulate rations and the degree of correct information can sometimes be swayed by the companies selling the product rather than by the principles of sound nutrition.

On our UK farms, we have an opportunity to grow high quality feed but this can often fall short of our expectations due to deficiencies in our soils or husbandry.

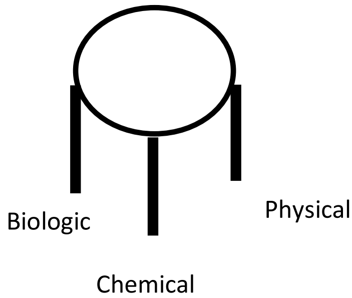
5.0. Soils

In this chapter on soils my aim is to summarise the main facts that were always referred to by the passionate men and women whom I met.

The most influential people I met in my study were Terry Hehir NSch, Matt Mahoney, Adam Williams NSch, Phyllis Titchinin, Jeff Williams, Garry Zimmer and Dr. Paul Dettloff. Case studies of my visits to these inspiring people are given in Chapter 7.

They emphasised that our soils have evolved over thousands of years, some formed from parent rock and some from vegetation, but should all be productive if in balance.

The diagram below shows the three pillars on which a balanced soil depends.



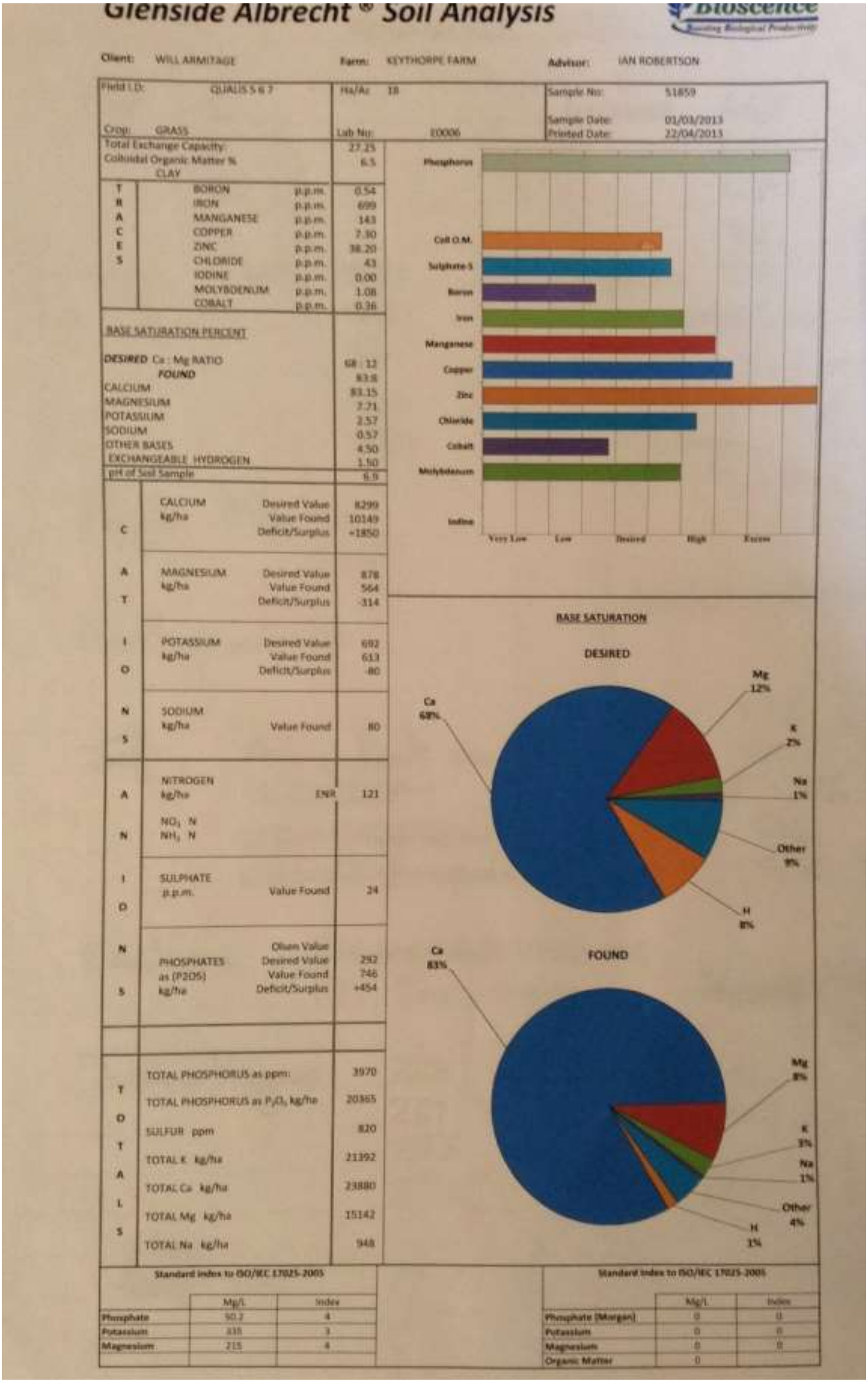
How can we ensure our soils are productive, robust and resilient and still in our fields for the generations to come?

A soil is most productive when it's able to retain moisture, air and microbes. Extensive work was done by Prof W A Albrecht to establish the correct BASE SATURATION LEVELS of minerals that need to be present to achieve this in any soil and yet, speaking to farmers, few can tell you what these are on their own farms.

> *Yet, speaking to farmers, few can tell you what the (Base Saturation Levels) are on their own farms*

On the **next page** I show a picture of an Albrecht Soil Analysis chart taken for my own farm. This chart is so revealing in the depth of the analysis that I have included it in this report, even though you will have to set your viewing zoom level to 200% to see it properly.

Base Saturation Levels are discussed in the following chapter.



Glenside Albrecht ® Soil Analysis

Bioscience

Client: WILL ARMITAGE | Farm: KEYTHORPE FARM | Advisor: IAN ROBERTSON

Field I.D: QUALIS 5 6 7	Ha/Ac 18	Sample No:	51859
Crop: GRASS	Lab No: E0006	Sample Date:	01/03/2013
		Printed Date:	22/04/2013

Total Exchange Capacity:		27.25
Colloidal Organic Matter %		6.5
CLAY		
TRACES		
BORON	p.p.m.	0.54
IRON	p.p.m.	699
MANGANESE	p.p.m.	143
COPPER	p.p.m.	7.30
ZINC	p.p.m.	38.20
CHLORIDE	p.p.m.	43
IODINE	p.p.m.	0.00
MOLYBDENUM	p.p.m.	1.08
COBALT	p.p.m.	0.36

BASE SATURATION PERCENT	
DESIRED Ca : Mg RATIO	68 : 12
FOUND	83.8
CALCIUM	83.15
MAGNESIUM	7.71
POTASSIUM	2.57
SODIUM	0.57
OTHER BASES	4.50
EXCHANGEABLE HYDROGEN	1.50
pH of Soil Sample	6.9

CATIONS		
CALCIUM kg/ha	Desired Value	8299
	Value Found	10149
	Deficit/Surplus	+1850
MAGNESIUM kg/ha	Desired Value	878
	Value Found	564
	Deficit/Surplus	-314
POTASSIUM kg/ha	Desired Value	692
	Value Found	613
	Deficit/Surplus	-80
SODIUM kg/ha	Value Found	80

ANIONS		
NITROGEN kg/ha	ENR	121
NO_3 N		
NH_4 N		
SULPHATE p.p.m.	Value Found	24
PHOSPHATES as (P2O5) kg/ha	Olsen Value	
	Desired Value	292
	Value Found	746
	Deficit/Surplus	+454

TOTALS	
TOTAL PHOSPHORUS as ppm:	3970
TOTAL PHOSPHORUS as P_2O_5 kg/ha	20365
SULFUR ppm	820
TOTAL K kg/ha	21392
TOTAL Ca kg/ha	23880
TOTAL Mg kg/ha	15142
TOTAL Na kg/ha	948

Standard index to ISO/IEC 17025-2005

	Mg/L	Index
Phosphate	50.2	4
Potassium	335	3
Magnesium	215	4

Standard index to ISO/IEC 17025-2005

	Mg/L	Index
Phosphate (Morgan)	0	0
Potassium	0	0
Magnesium	0	0
Organic Matter	0	

6.0. Base Saturation Levels

Base Saturation Levels mean the total amount of mineral within the soil, available or otherwise. The chart on the previous page shows, in the top pie chart, the ideal level of the main minerals in soil.

When you look at the Base Saturation Levels at Keythorpe (*my farm – in the chart on previous page*) you can see we have tonnes of calcium and phosphorus in our soil which is available if we maintain and enhance the soil biology. The soil biology creates the vital links between the mineral in our soil: the plants: the animals: and ultimately the nutrient density of food.

In order of percentage required:

6.1. Summary of main functions of main minerals

	Mineral	Role
THE BIG 4	Calcium	Central role in plant health and soil health.
	Boron	Root growth, cell elongation, plant health and uptake of calcium.
	Magnesium	Found in the centre of chlorophyll molecule, the plant's light harvesting energy producing centre. Production of oils and proteins and energy metabolism
	Phosphorus	Associated with energy because plants store energy in phosphate bonds. Important for healthy roots and crop quality as its part of the plant's cell membrane.
	Nitrogen	Found in the protein molecule in enzymes and the chlorophyll molecule.
	Potassium	Metabolism in plant, plays a role in sugar movement within the plant, enzyme production, water balance and plant growth.
	Zinc	Enzyme activator important for growth and flowering.
	Iron	Production of the chlorophyll molecule
	Manganese	Needed for photosynthesis and enzyme activator.
	Copper	Cellular function and enzyme production, sugar production and movement in the plant.

6.1.i. Calcium

Calcium is a vital element that is often overlooked:-

- Calcium is the driver for energy flow in the soil and deficiencies equate to poor soil structure and microbe function. Without calcium growth will be limited.
- PH and calcium should not be confused. A soil can be deficient of calcium even with a reading of pH7. Soils need **available** calcium regardless of pH.
- Soil microbes and humus colloids chelate Ca, making it plant available.
- Plants recycle Ca back to the soil by the flaking of root cap cells and plant deaths.

- Calcium is essential for:-

    - Soil microbe growth
    - Soil energy flow capacitance
    - Soil mineral mobility
    - Balancing Mg availability
    - Heavy metal detoxification
    - Foliage photosynthesis
    - Complex carbohydrate and protein synthesis
    - Phototropism and Gravitropism

Ca affects almost every physiological factor. It is the primary base against which other materials are reacted to release energy.

Plants need a constant supply of Ca especially during initial spurts of growth as it provides vegetative growth energy. If available Ca is low, growth will cease.

When high levels of available calcium are in balance with other nutrients in the soil, plants absorb more nutrients resulting in nutrient-dense high-integrity produce.

If there is insufficient available Ca in the soil the health of every level in the food chain is compromised.

Leaf Brix is an indicator of Ca availability through its effect on soil energy and photosynthesis. Until the threshold of Ca availability in the soil is above 3,000 kg/ha, expect poor soil life and structure, mineral uptake, photosynthetic performance, brix levels and nutrient density.

A soil high in calcium will have more oxygen, drain more freely, support more aerobic breakdown of organic matter.

A soil high in magnesium will have less oxygen, drain slowly, organic matter may ferment and produce alcohol and even formaldehyde both of which are preservatives.

In clay soils the ratio should be:	70% Ca : 10% Mg
In sandy soils the ratio should be:	60% Ca : 20% Mg

Calcium is the trucker and drives the uptake of all minerals into the plant.

6.1.ii. Boron

Garry Zimmer (President of Mid Weston Bio Ag in the States) calls calcium the trucker and says **boron is the steering wheel.**

- Boron works in synergy with calcium and has to be present for maximum calcium uptake.

- Boron plays a role in plant growth, flowering and grain fill, yet its importance in crop health is often overlooked.
- Boron is needed for root growth, cell elongation, plant health and uptake of calcium.
- Applying calcium without boron is a lot less effective than applying them together.

6.1.iii. Magnesium

Magnesium is essential to plant growth because it is found at the centre of the chlorophyll molecule that captures the sun's energy. If magnesium is missing, photosynthesis will be reduced.

- Magnesium is important in the production of proteins, oils and energy metabolism in plants.
- Magnesium is difficult to get into plants and this can be related to the magnesium potassium levels in the soil; the more soluble potassium available to the plant, the less magnesium the plant can absorb, resulting in a magnesium deficiency.
- Applying sulphur is one way to get more plant-available magnesium.
- Sulphur will lock onto magnesium in the soil forming magnesium sulphate (Epsom Salts) which is very soluble and plant available.
- A healthy soil, high in biology, will have more available magnesium.

High magnesium levels in tissue samples are an indicator of good soil health. Compacted soils, over-tilled or over-fertilised with soluble nutrients, will have low magnesium levels and therefore decreased photosynthesis and output.

6.1.iv. Phosphorus

Phosphorus is very important for photosynthesis, flowering, fruiting, nitrogen fixation and plant maturation as well as root growth, and stem strength.

- Phosphorus needs to be active and cycling within a soil; not leaching, eroding or getting tied up.
- Phosphorus has a strong negative charge and ties up very easily with other minerals in the soil.

Soils that are low in biology, organic matter, or are compacted, will struggle to make phosphorus available to the plant. According to the University of Wisconsin, bulk spread DAP (Diammonium phosphate) starts to lock up within two hours of being spread. **Applying soluble phosphorus does not mean it is available to the plant.**

Soil biology, and in particular mycorrhizae fungi, is vital for the phosphorus to be plant-available.

A healthy soil high in biology will have more available phosphorus.

High phosphorus levels in tissue samples are a good indicator of good soil health.

6.2. Soil samples

There are numerous soil analyses but few give a true reflection of the health of your soil.

The majority focus on P, K, Mg and pH, a very blinkered approach, ideal for fertiliser salesmen who are trying to sell you something. But very often destructive rather than constructive advice follows, with recommendations to use high levels of soluble fertiliser, which can further lock up other minerals, burn off carbon and reduce soil life. You will still grow a crop, but with low mineral density, susceptible to pests and disease; and therefore more chemicals will be required.

How can yields of crops increase and their mineral content remain the same if those other minerals are not applied or not available in the soil? Soil and plant biology with good TLC has the ability to out-perform chemical agriculture when you look at the total mineral diversity of the crops grown, and it is this efficiency and synergy that will ultimately equate to a farmer's livelihood and profit.

A New Zealand study looked at the nutrient densities of organically grown pastures versus conventionally grown pasture. See chart below – you will probably need to increase zoom levels.

TABLE 5 Nutrient densities[1] of biologically grown pasture vs conventionally grown pasture

Treatment	N	P	K	S	Ca	Mg	Na	Cl	Fe	Mn	Zn	Cu	B	Mo	Co	Se
	(%)								(mg/kg)							
Biologically grown pasture	3.24	0.39	3.20	0.40	0.62	0.23	0.17	1.04	159	89	178	6.8	5.8	1.43	0.19	0.19
Conventionally grown pasture	3.40	0.42	2.98	0.32	0.59	0.25	0.22	0.93	120	59	150	6.8	5.4	1.66	0.07	0.07

1 Mean of 5 cuts taken in the autumn and spring. Data from the first year of field trials on a Waikato dairy farm; courtesy of Abron Living Soil Solutions

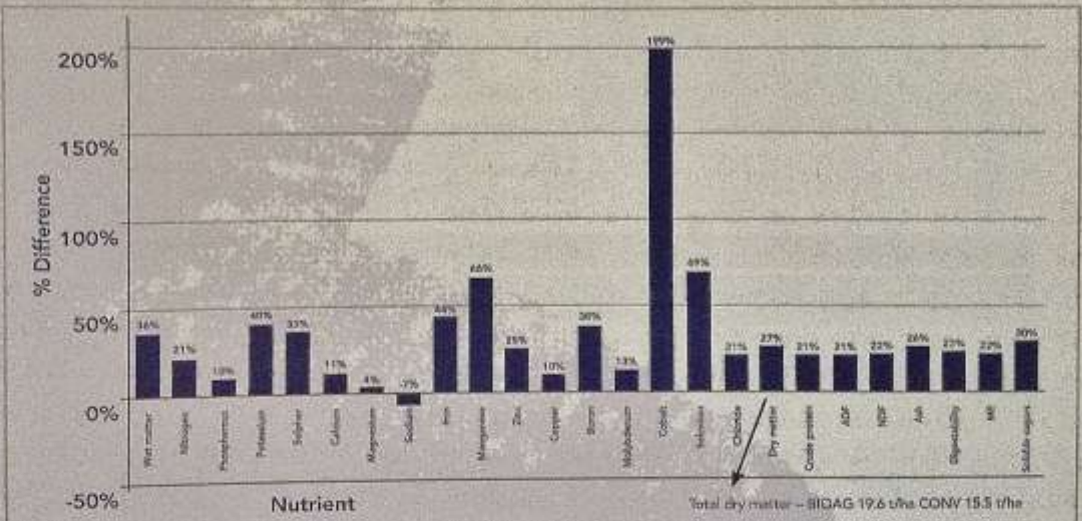


FIGURE 2. Nutrient level improvements of biologically grown pasture versus conventionally grown pasture on a Waikato dairy farm. Values represent the mean of nine analyses of samples taken over an 11 month period and adjusted for differences in total dry matter production; courtesy of Abron Living Soil Solutions

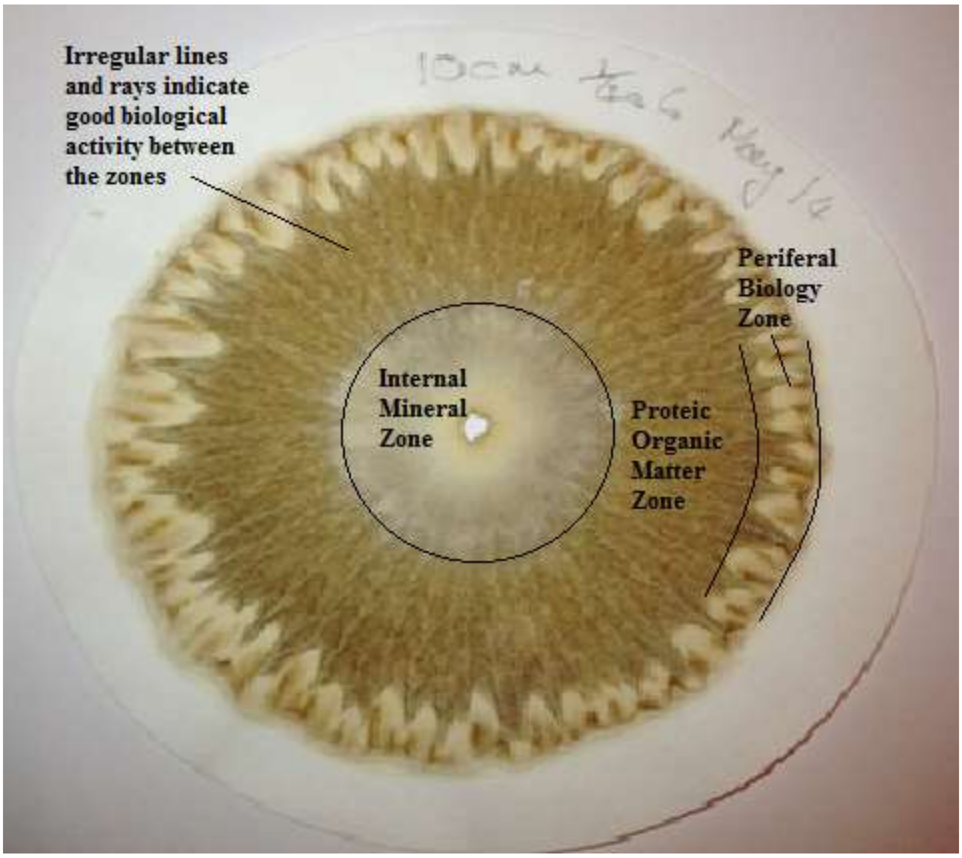
6.3. Soil chromatography

Of the soil analyses I have looked at, I find the Albrecht method is a good indicator of the total mineral content. However, it does not show the level of biology in the soil - how well the soil is working - and so the availability of those minerals is not measured.

In June 2014 I attended a Regen Ag Bio-fertilisers Course with the aim of seeing how we can increase the efficient use of our on-farm cow slurry and FYM. I will cover this later in the report, but will now explain soil chromatography and how it's a good visual indicator of soil health, the amount of mineral, organic matter and biology, and the interaction between the three.

The basic process is to make a soil solution, prepare a filter paper using silver nitrate and then allow the filter paper to suck the soil solution through a short straw from a petri dish. As this occurs the solution spreads through the filter paper. The heaviest material - the mineral - stops first, the organic matter stops spreading second, but the biology and enzymes carry on.

The papers have to dry for about two days before you can see the full effect and at that point you are able to see the interaction between the zones.



Soil Chromatography is a visual assessment.

The Internal Mineral Zone should be a cream colour. Violet/black is an anaerobic/chemical soil. White is a bleached soil rich in soluble N.

The Proteic Organic Matter Zone should be wide and a rich lightish brown colour. If there are defined lines between the zones it means there is very little interaction between the zones with mummified biology and the mineral flow to the plant will be very poor.

The Peripheral Zone indicates the enzyme activity in the soil which is vital for good soil health.

Here are a few examples of soil samples using chromatography:

1. High glyphosate

2. Soil sample taken at 50 cm depth at Keythorpe - my own farm

   Note the high mineral content in the centre and the low organic matter in the middle band with less interaction between each zone.

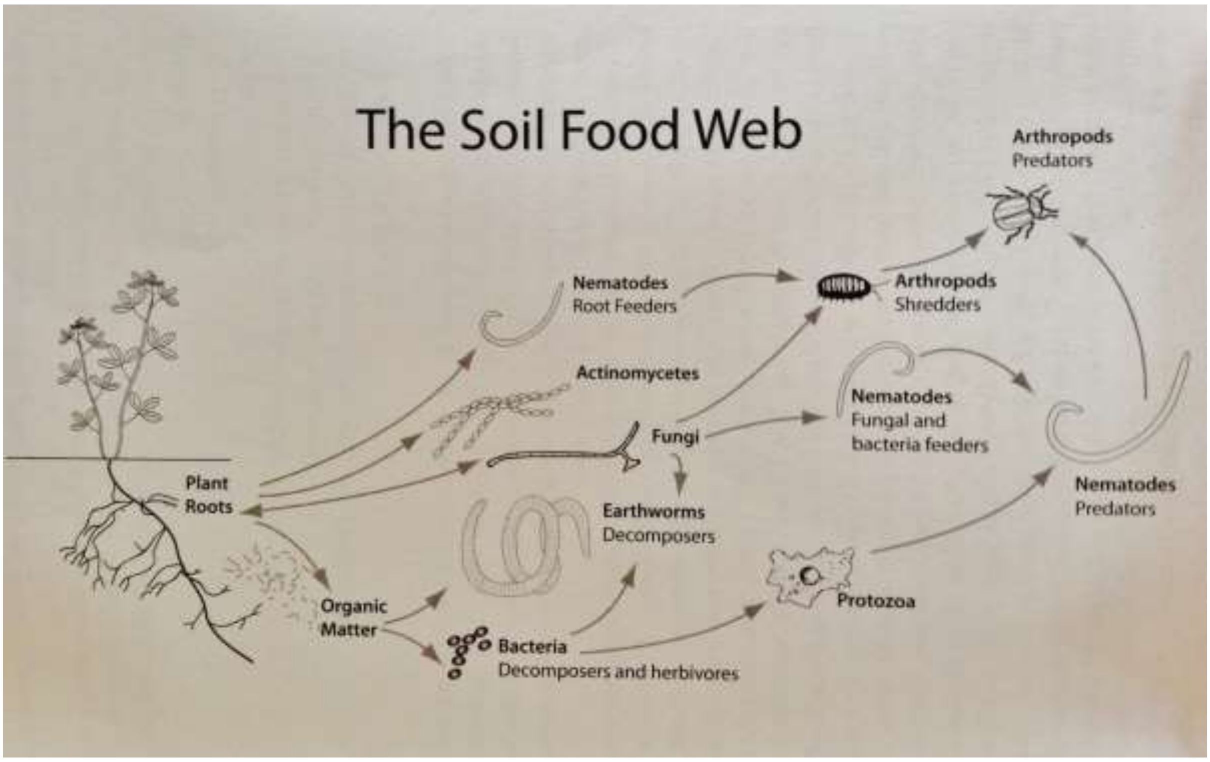
3. Soil samples taken at 10 cm (depth) Keythorpe – my own farm

   I was very pleased with this chroma . It shows good mineral and organic matter levels with excellent biological interaction between the zones.

6.3.i. Summing up of visual assessment of chromatography samples

Very Good	Very Bad
Regular rays and irregular zones Browns Oranges Yellows Cream colours  Keythorpe soil at 10 cm depth	Irregular rays and regular zones Black Blue Purple White  Sample taken from a mango grove where glysophate had been used for years for ground weed control

6.4. Soil biology – soil life



The Soil Food Web : Chart to demonstrate soil biology (Wikipedia)

> **Soil Biology means the livestock <u>under</u> the soil: e.g. earthworms, bacteria, fungi, nematodes and arthropods**
>
> **We know that science has only studied a fraction - possibly as little as 1% - of our soil biology.**

We know that science has only studied a fraction - possibly as little as 1% - of our soil biology.

In a healthy soil it is estimated that there are 1,000 kg of livestock/acre that we don't see; living, breathing, reproducing and maintaining the vital nutrient links between the soil and plants; these include mites and earthworms, fungi bacteria, amoeba and nematodes.

What we do know about our soil life - and the massive impact it has on the health of our soil - is that soil biology retains nutrients.

Nutrients are held in the bodies of the micro-organisms, earthworms and all living creatures in the soil. The nutrients are temporarily tied up while they are alive but when these organisms die and decompose the nutrients become available for other organisms to consume.

If you have 20 earthworms/square foot you have nearly 1 million/acre. An earthworm has a four year life cycle and, as one quarter of them therefore die each year, 120 units of nitrogen/acre are released into the soil.

Plant residues contain nutrients but these are not immediately plant available. They first have to be broken down by the soil life before the minerals are released back into a plant-available form.

Highly decayed plant residue and soil life eventually turn into stable organic matter known as humus.

Humus retains nutrients in the soil because it has a high CEC (cation exchange capacity) nutrient holding capacity.

In a healthy soil it is estimated that there are 1,000 kg of livestock/acre that we don't see; living, breathing, reproducing and maintaining the vital nutrient links between the soil and plants

The more soil/biology life there is, the more humus there is, the higher the CEC and the higher the fertility of the soil.

6.4.i. Soil biology converts nutrients into a plant available form

Most nutrients in the soil are not immediately available to plants. They have to be broken down by the soil life – these include nitrogen, sulphur and manganese and others.

It is the enzymes produced by the micro-organisms in the soil that separate the nitrogen from the carbon making it available to the plants.

The higher the soil biology, the more mineralisation that can occur, so the higher the fertility.

Rhizobia are a type of bacteria that are able to take nitrogen from the atmosphere and convert it into ammonium which is the plant available form.

These rhizobia colonise the root hairs of legumes forming root modules.

The plant and bacteria form a symbiotic relationship where the host plant provides the bacteria with carbohydrates which the bacteria use for energy and the bacteria supply the host plant with nitrogen.

Applying soluble nitrogen will shut down these natural nitrogen fixing systems.

Earthworms consume soil particles and organic matter as they burrow through the soil and excrete casts which are very rich in plant available nutrients. These burrows are then used as paths for roots to grow in a very fertile environment.

6.4.ii. Soil biology transports nutrients and water to plant roots area

Mycorrhizae are a fungi that form a symbiotic relationship with plants. They colonise plant roots and grow out to form a huge net in the soil that captures water and nutrients and brings them to the plant.

Mycorrhizae are best known for bringing available phosphorus to plant roots, but they also capture zinc, manganese and copper, providing protection from pathogenic fungi and parasitic nematodes.

In exchange, the plant provides these fungi with carbohydrates and vitamins essential for their growth.

Phosphorus is tied up very easily in the soil so applying soluble phosphorus to a field does not guarantee high levels of phosphorus are available for the full growing season and, as with rhizobia, the soluble phosphorus will shut down the mycorrhizae fungi.

It is the soil biology, especially mycorrhizae fungi, that delivers phosphorus to the plant.

6.4.iii. Soil biology Improves soil structure

Soil biology works the soil with earthworms and other small mammals, burrowing and creating channels for air, water and plant root. This movement helps keep the soil loose, crumbly and well aerated with good water retention.

Another substance only recently discovered in 1996 is Glomalin. This is a sticky material secreted by fungi that is very resistant to decay and plays a key role in stabilising soil aggregates - the loose clumps of soil that hold soil carbon and allow roots to grow.

6.4.iv. Soil biology suppresses disease

When soil biology is high and the food web is complete and working, no one population of organisms overpopulates. This includes disease organisms because good organisms in the soil will out-compete or eat them, keeping the disease population in check.

Organisms compete for space and food and every organism has to defend itself against attack. A common method of defence is to give off toxins to ward off predators. Two of these are penicillin and streptomycin – both naturally occurring antibiotics in the soil that micro-organisms secrete to kill the bacterial infection.

There are undoubtedly other antibiotics given off by soil organisms that we have not yet discovered.

6.5. Soil organic matter – soil carbon

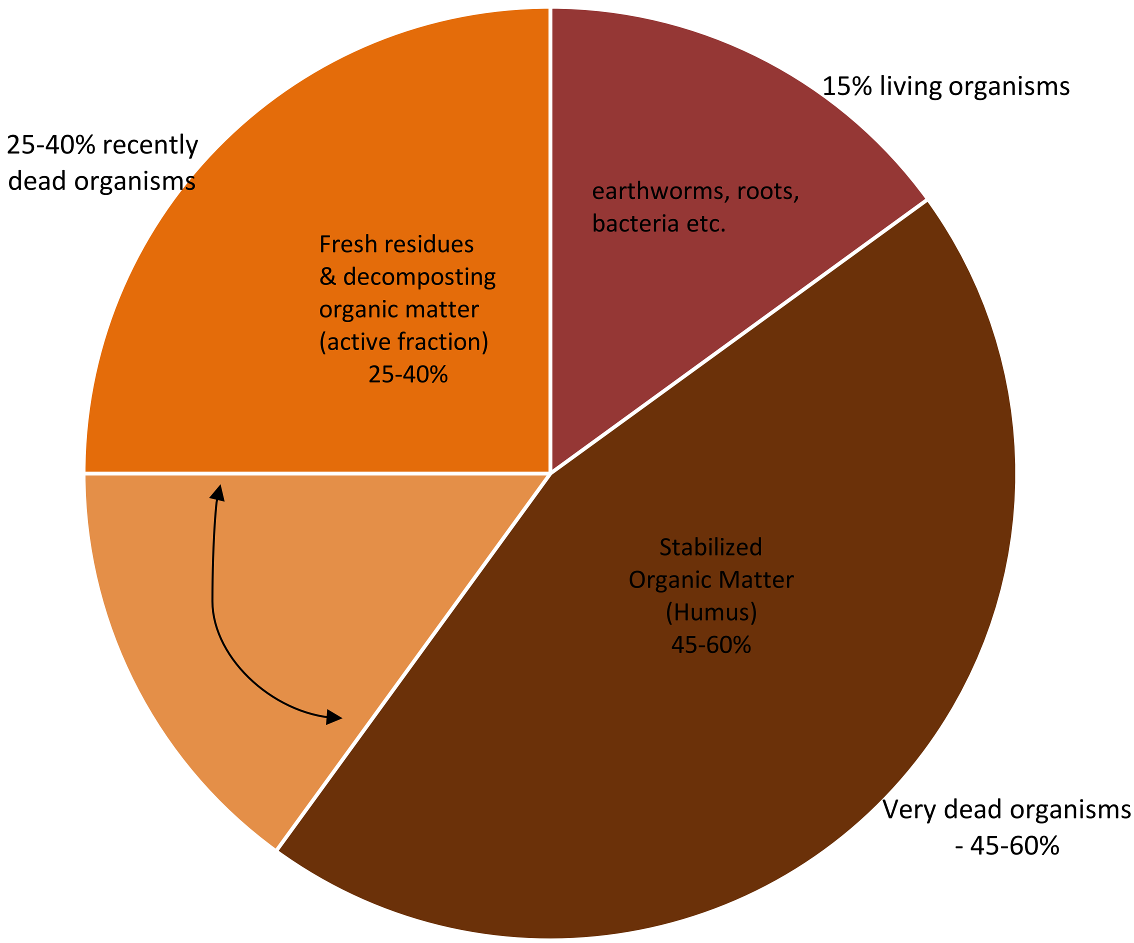
Soil organic matter can be broken down into three groups:

- living organisms as I spoke about in the last chapter
- recently dead organisms, fresh plant and animal residues, and decomposing organic matter
- stabilised organic matter humus.

4.5.i. Components of organic matter

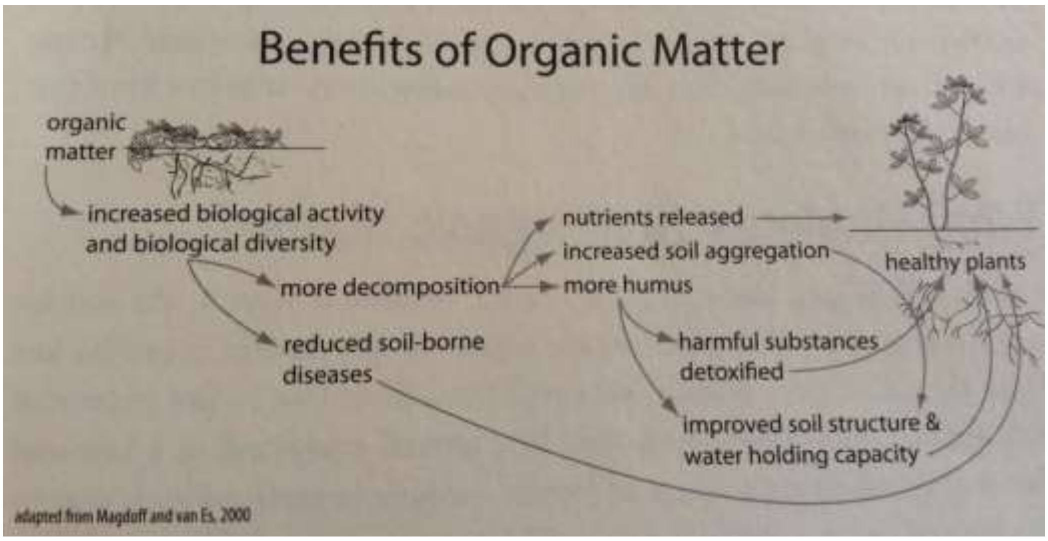
Total soil organic matter will usually range from 1-5% of the soil. Although only a small percentage, it is vital for soil health; improving soil structure, retaining soil nutrients and converting nutrients to a plant available form that can then be stored by the humus with its very high CEC until required by the plant.

(See chart on next page)



Components of organic matter

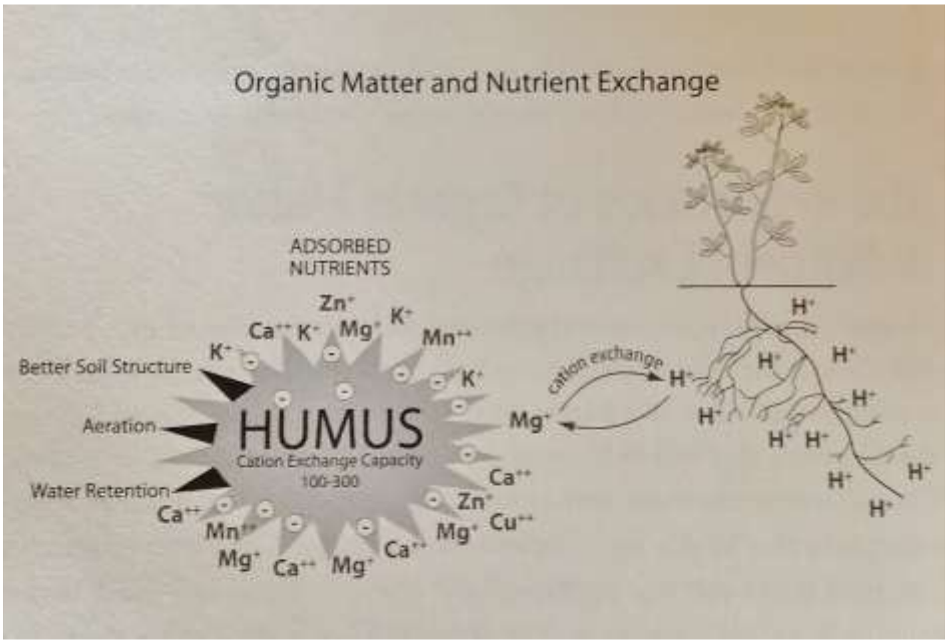
6.5.ii. Benefits of soil organic matter *(adapted from Magdoff 2000)*



Humus does not lock up nutrients but they are held loosely, which means they are easily exchangeable with plant roots - making it an ideal storage system for the soil.

If you apply chemical nitrogen to the soil and it is not taken up by the plant quickly the free N will break down the humus and it will be lost – so reducing the nutrient holding capacity of your soil.

6.5.iii. Organic matter and nutrient exchange *(courtesy of Garry Zimmer)*



As you can see from the diagram – if humus is lost, many plant-available nutrients will also be lost, leaving the plant potentially deficient in nutrients; resulting in poor plant health and a lower integrity mineral density of the plant. This is the start of the food web, and if integrity is lost in this initial stage, health and immune function will be compromised from then on.

7.0. The passionate soil mineral men and women

It is now time to give some real life examples, taken from visits made during my Nuffield Farming study tour travels.

7.1. Terry Hehir

It was a statement made by Terry Hehir, NSch, that he "was growing an inch of top soil a year" on his farm in Wyona, South Australia, that really focussed my mind - being a farmer's son, loving the land, and having recently bought a farm - hearing how I could increase and improve my costly asset was music to my ears.

In November 2013 I visited his 600 cow dairy farm. Terry had formerly been farming a high input, high output Holstein herd very similar to where I had been in the 1990s, but became disillusioned with the costs of the inputs and the way any margin he made was handed back to the suppliers.

It was at this point he started to use the Albrecht system, looking at the Base Saturation levels in the soil and, with some advice, he started to apply high levels of calcium to his high magnesium soil. Within a relatively short space of time the physical characteristics of his soils had changed. They were less compact, with improved water retention and, as a result, the dry matter yields increased. His cows produced more milk from forage and his cow health improved to a point at which he decided to convert to organic. Terry's son, Brendan, and his team have not used an antibiotic tube for 13 years, and when I saw their cows they had silky skins, excellent muscle tone and were performing really well.

Brendan Hehir with some of his cows showing their excellent condition.

Their farm is a dry land farm with irrigation and, when I visited, they had just invested in a new flood irrigation system on a block of land where they were growing lucerne that was yielding a massive 20 tonnes DM/Ha. They spread calcium on their land in the early spring and early summer and also applied molasses, humates and trace minerals, usually after every second grazing.

The Hehirs had just invested in a new flood irrigation system on land where lucerne was producing 20t DM/Ha

The grazing paddocks were mixed grasses and clover and some lucerne was also grazed. With the diverse forage and the fertiliser policy following the Albrecht system, high integrity, nutrient dense forage was being produced that was demonstrated in the health and strength of the cow.

7.2. Matt and Vickie Mahoney

Matt and Vickie Mahoney farm in South Victoria, Australia. They used to have a 9,000 litre p.a. herd but had become fed up with most of the profit margin being paid back to suppliers.

Matt was very passionate about his soils and the overall balance on his farm. He attended a number of courses to study the Albrecht soil test and its ramifications.

Matt Mahoney farmed 750 acres of high magnesium soils with a 650 ml rainfall and now has 360 cows that were in excellent condition; quite large, very capacious cows. They grazed long grass, not the 2,800 kg DM/Ha (3 leaf stage) covers that I am used to.

Matt had been working with diverse swards and was hoping to stop reseeding in future. He had moved from mainly ryegrass swards to ones that were high in timothy and fescues with lucerne, clover, chicory and plantains. He expected he would have to let the sward mature and set seed, and then mob-graze the paddock with dry cows, whose action would return the seed to the soil to maintain the diversity and density.

Matt Mahoney's large, capacious cows

Matt was adamant that we must put energy into the soil to feed the biology so he was using CSR calcium, which was pure calcium ions stuck to an energy source - usually sugar - that he sprayed onto his land with an additional 5% molasses added to his tank mix.

Matt insisted that mineral balance is the key to maximising dry matter yields, and that pasture efficiencies can only be achieved when the calcium phosphorus ratio is 1:1 in a foliar sample.

He used a refractometer to measure the Brix in his sward and was aiming for a Brix of 12 and a pH of 6.4 – if he achieved this, the plant would exude 50% of the sugars produced by photosynthesis, back to the soil, which would create the momentum for the next growing cycle. (*See picture on next page*).

If Matt had a paddock that was low in organic matter, he would grow oats with grass and lucerne that would be grazed twice, then cut and then grazed allowing a lot of organic matter to be trodden in to feed the microbes.

Matt Mahoney's refractometer to measure the Brix in his sward

Matt also composted any manure he had with wood chip and put any dead stock into the heap "*A dead body is far too valuable to allow it to leave the farm*". It was taking 90 days to compost a cow with only the largest bone still visible – and such bones were very brittle and usually smashed up when spread. UK farmers should question current legislation which prohibits the composting of dead stock on farm.

I spent a day and a half with Matt and as we chatted he came out with numerous facts:-

- All forms of life must maintain a pH of 6.4; energy must be supplied with the correct mineral balance.
- Energy robs body reserves so if a mineral imbalance occurs the immune system will be challenged leading to ill health.
- The human body rebuilds itself in three years so there is a massive opportunity to significantly improve your health with correct nutrition.

- History shows us that when populations deplete soil reserves, food integrity reduces, people eat an imbalanced diet and an excess of energy depletes minerals that causes ill health, unrest and the civilisation to die out.
- The Egyptians survived for 10,000 years mainly due to the Nile flooding and replenishing soil nutrients every year.

It was some of these quotes that added some clarity to the direction of my Nuffield Farming study tour.

Matt's compost - manure, wood chip and any dead animals

7.3. Phyllis Titchinin

Phyllis is a Biological Farming Consultant, Educator and General Manager of True Health based in Hawke's Bay, New Zealand.

I spent two days with Phyllis, on her farm. She has a massive wealth of knowledge and after the time spent with her I really felt that I could start linking my Nuffield Farming study together with some clarity. She also gave me some excellent contacts to further my study and fed me very well with plenty of dairy products – she's a true believer in animal fats and brain function. See some of Phyllis's statements below:

- Soil carbon is not a measure, as a lot is not soluble. Humic contents must be the measure in the future.
- Humates are the most complex substances on earth.
- Soil microbes are one part N and 5 parts carbon so will not survive in a highly fertilised soil. Calcium is king. 500 kg – 1,000 kg of calcium is required/ha/year regardless of pH.
- Calcium makes foliar feeds more efficient.
- 1 kg excess urea will burn off 100 kg of soil carbon. The physics of soil have not ever been talked about, let alone understood.
- When a plant reaches a Brix of 12, it will absorb minerals from the air.
- Maintain a Brix level of 12, and this will ensure the sugars are complex and true proteins are formed which will almost eliminate pest and disease attack. Pests cannot digest complex sugars so they won't attack the plants.
- We need to work with competitive exclusion; instead of killing the bad, enhance the good and out-compete the bad.
- According to USDA figures, nutrient density of feed in 1990 had reduced to only 60% of what it was in 1948.
- Biophoton particles in humus provide a light source in the soil.

Phyllis works very closely with Dr Paul Dettloff of True Health, whom I later met in America.

I quote below from an article Phyllis wrote in conjunction with Dr Paul Dettloff.

> ***Getting Fully Mineralised Soils***
>
> *All disease starts in the soil … a bold statement, but basically true. The quality of what we eat – its vitamin, mineral and enzyme content – determines our health. We can't grow strong bodies and robust immune systems without the proper mineral building blocks in our foods. Those building blocks come from the soil and are made available to the plants and animals through soil microbes. So to get nutrient dense, flavourful, pesticide free crops food, we need to make sure our soils have well balanced minerals, including trace elements, and a lively, diverse community of beneficial microbe s.*
>
> *The most effective way to achieve well mineralised soils is to focus on getting generous amounts of calcium into the soil and the microbes. Most soil tests list the Base Saturation*

percentages for the positively charged elements Calcium, Magnesium, Potassium and Sodium. These percentages should be around 70%, 15%, 4% and 1% respectively.

Orientate your fertilizer program to reach those percentages, focusing on calcium, magnesium, boron and phosphorous. Most New Zealand faming soils already have good levels of phosphorous but it is locked up with iron, aluminium or calcium. Soil microbes can break those chemical bonds that are keeping phosphorous locked up. Microbes don't like chemicals, so try to ease off chemical usage where possible, using less eventually helps to make phosphorous and other minerals more available to the plants for better yield and greater nutrient density.

Adding a complex carbon source to your fertiliser, such as quality humic acid granules, helps to keep the fertilizer in the root zone and the carbon stimulates growth of the soil microbes.

The sooner you get your calcium levels to the optimum, the sooner the other minerals become more available to the plants and the happier the microbe community will be --- Calcium is King.

Mixed sward with Brix of 12

7.4. Jeff and Janice Williams – Palmerston North, New Zealand

My visit to Jeff was very interesting. He had originally been a conventional New Zealand grazier, and had then invested in concrete and a feeder wagon and had increased yields but now he'd parked up the feeder wagon and bought a tow-and-fertiliser machine and was farming biologically. He is now growing 16t DM/ha+ on only one quarter the amount of N that he used to apply – he now applies only 50 kg N/ha.

Jeff had 320 Holstein and cross-bred cows calving in two blocks to keep a level supply of milk. This two-block system did create some cost in the business but was paid for by the additional premium for the out-of-season milk and the bull calves (which also obtained a higher price out of season).

Fresh calved cows ran with the calves and were milked once a day.

Pastures were mixed swards of either ryegrass with clover, chicory and plantain; or fescues with chicory and plantain – this was because he felt the fescues were optimised on a 20-25 day round and the ryegrasses on a 30 day round.

When Jeff had formerly been using 200 kg N/ha his cows were always challenged with foot problems, mastitis and infertility and, as a consequence, profitability was always under pressure. "*The system had to change*", he said.

He started with the soils and looked at the base saturation levels, finding the calcium:magnesium ratio was imbalanced and that calcium needed to be applied.

So at that point Jeff took a step back, looked at his cows and soil health, and decided to do something about it.

He started with the soils and looked at the base saturation levels, finding the calcium:magnesium ratio was imbalanced and that calcium needed to be applied. He was not confident about going organic with the grazing pressure there would be on his platform so he looked into ways of minimising the nitrogen applied as any excess would burn off organic matter and reduce soil health, so compacting his soils further.

Jeff Williams

He looked into foliar feeds that he could make and apply as and when required.

It was at this point he bought his Tow-and-Fert machine – "*The best bit of kit I have ever bought*," he said.

Jeff with his Tow-and-Fert machine

This fertiliser applicator mixes various solids with water or liquid that is then applied in suspension to the crop. Jeff was mixing:

Crystal calcium nitrate
Limestone flour
Humates
Salt
Molasses and water

That was then applied using the Tow-and-Fert with GPS behind his truck, which was usually after every second grazing. The rates of the humates and salt would vary according to the paddock, but the nitrogen was usually only 8 kg/ha – the calcium 20 kg/ha and the molasses 10 kg/ha.

Jeff was also running some laying hens behind the cows which was a very easy and profitable enterprise to bolt on to his existing dairy unit. The chickens were in a towable chuck caravan and took 30 minutes to look after each day. He was aiming to run five sheds and employ a part timer to look after them. He sold the eggs at the farm gate and, being on the edge of Palmerston North, his customer base was large and keen to buy his eggs.

Jeff was convinced that the chickens not only added to the farm income but also helped improve his pasture, with the chucks scratching and cultivating the base of his sward, thereby stimulating soil biology and releasing more minerals to feed the plants.

He also felt there was a strong symbiosis between cow and chicken muck that was beneficial to his pasture.

Jeff's hens in their chuck wagon

Jeff was working on a four week rotation; the cows would graze the paddock, one week later the chucks would start to rotate around that paddock giving them about 1/10th of the area, fenced in with flexi-net with their caravan in the centre. Once a day he would collect the eggs, drop the fence, pull the caravan onto new ground, feed the hens with milk and grain maize, then put the fence back up around the new area – all very quick and easy. The hens would then be taken off the paddock two weeks before the cows came back to that paddock.

As a result of these changes, Jeff is now growing top soil. The soil structure has improved massively, crop yields have been maintained and cow health has improved dramatically as the integrity of the feed has improved.

Soil structure and depth of top soil have both improved under Jeff's new regime

When Jeff looks back to his old business model he said he can see where his margin was going - out of the gate. He is now under far less pressure in all aspects and feels he has taken back control of his and his family's future; he is now thinking of selling raw milk and setting up a farm shop.

Jeff's comment on GM: "*It is pure arrogance to think we can beat nature*".

8.0. Plants

Soils exist in a symbiotic relationship with plants and animals.

- Plants cannot live without animals, soils cannot exist without plants, and animals need both for proper nutrition.
- Plants carry minerals, protein and energy from the environment to our table and the type of plants we grow will vary in the nutrients they deliver.
- The way we grow these plants can also have a massive impact on the mineral, protein and energy density of the food produced.
- Plants must exude nutrient into the soil to keep it alive.

There are very few successful monocultures in the natural world and diversity is key to a resilient eco system and yet, in agriculture, we continually try to simplify and cheapen our farming systems with monocultures or minimal rotations.

Monoculture farming has exposed the world to a high risk of famine - this has been highlighted over the years with the Irish Potato Famine 1845-1847 and also in 1970 when the US corn crop was wiped out by disease causing a loss of over a billion dollars in production (*USDA figures*).

Plant diversity builds resilience in a soil and farming system and is fundamental to the existence of our planet.

As I travelled it was apparent that most successful dairy operations had embraced plant diversity mainly as mixed swards but some were using single stands that were rotated quickly around the farm.

Mixed sward: tall fescue, Lucerne and red clover

There are numerous benefits to adding plant diversity to your farming system.

Rooting depth and root type diversity has many advantages:-

- The deeper the root the more water and mineral is potentially available to the plant.
- The larger the root mass, the larger the surface area for absorption and anchorage and the better the soil drainage with the roots creating channels through the soil.
- Increasing plant diversity will increase microbe diversity as different plants interact with different soil microbes.
- Different plants will access and draw up different nutrients from the soil so making use of more plant-available nutrients.
- Plant diversity can reduce the risk of pest and disease attack as many pests prey on a small range of plants.

8.1. Olaf Jansen

Olaf is a farmer and botanist I visited in Sweden in June 2013.

He farmed 800 ha organically, 1,100 ha of forest and had 340 dairy cows.

Cows	Litres	Butterfat %	Protein %	Calving intervals
230 Holsteins	10,700	3.91	3.21	13 months
110 Swedish Reds	9,200	4.03	3.34	11 months

He grew all his own food and was adamant that plant diversity and crop rotation were key to the success of his business.

Olaf used a seven year rotation:

Year	Crop	Seed mix
Year 1	Wholecrop	80 kg/ha spring beans and 160/ha wheat undersown with a ley mix which was sown at 45 kg/ha: 25% lucerne 10% red clover 5% white clover 35% timothy 15% rye fescue 5% meadow fescue 5% ryegrass
Year 2	Silage x 3 cuts	
Year 3	Silage x 2 cuts	
Year 4	Winter OSR	
Year 5	Winter Wheat/triticale	
Year 6	Field beans + wheat combined	
Year 7	Oats or triticale	

His forage quality was good, averaging 16% protein. He then made his own concentrate at 21% protein that he mixed with his forage to end with an overall protein of 17.5% - he felt that was the optimum for his cows, given the amount of milk they were producing.

He ground all his own feed through a disc mill and with whole OSR going into the meal mix he had a meal with an ME of 15 and an oil of 73g/kg.

His cows looked really well with great skins – they were bright and alert when I saw them, and grazing in a mixed sward with the same ley mix as above. He was not concerned with any potential bloat problems.

As he had been a botanist and studied for many years, it was very useful speaking with him. Olaf believed diversity held the key to agriculture's future with the synergies that could be achieved between crops and sound rotation.

One of Olaf's swards – recently established

Mature wholecrop beans/triticale/oats

8.2. Kenneth Sobye

Kenneth, the product manager for Limagrain, took me to visit a number of good farms in Denmark - some very high tech conventional farms, but one stood out and that was an organic farm with 130 cows yielding 9,500 litres and growing all their own feed - maize, lucerne, grass and rye plus the concentrate mix.

Hans's home grown concentrate was a mix of spring wheat, lupins and peas growing in a single stand that he combined and then heat-treated through a home-made drying system which comprised essentially a long auger that turned very slowly with a fire built around it. This cooked the feed and so reduced the protein deamination in the rumen - meaning he had more bypass protein for the small intestine to digest.

Hans's mix of spring wheat, lupins and peas

His aim was to achieve 180°C for 24 minutes. Unfortunately he could only spare me a little time in his fields so I did not see this in operation, but his crops looked fantastic. He was running a 5 year rotation on his arable block:

Year 1	Rye undersown with lucerne
Year 2	Lucerne
Year 3	Lucerne
Year 4	Maize
Year 5	Tri crop: spring wheat, lupins and peas

Triticale, lupins and peas

9.0. Growth heights and root depths of forage species

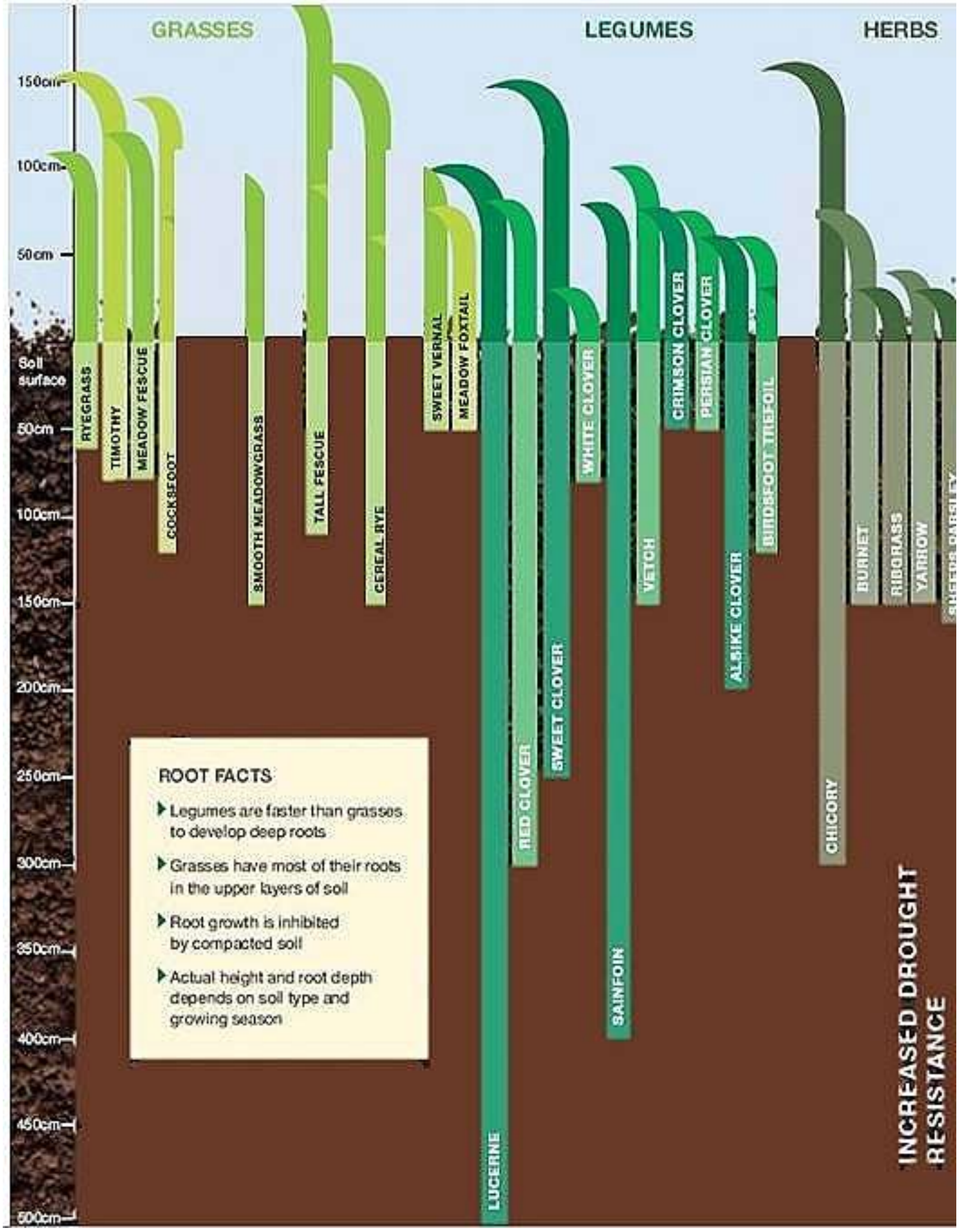


Diagram of growth heights and root depths of forage species (*graph from Cotswold Seeds Ltd.)*

It would be impossible to discuss the many plants and crops that I saw on my travels but I will briefly highlight the benefits of the most common plants being used successfully on the dairy and mixed farms I visited.

9.1. Deep rooting plants

Lucerne, red clover, chicory and plantain were all common on farms I visited.

Lucerne and red clover are not only very deep rooting and are able to mobilise minerals from deep in the soil, but are legumes that fix nitrogen from the air in the soil; which can then be used by other crops being grown in the same stand, or stored in the root nodules to be used by the next crop in the farm's rotation.

I have used lucerne and red clover for many years on farm and have seen massive benefits from growing and feeding them to cows and it was the lucerne that gave me the confidence to change to organic farming. Lucerne and red clover will both supress weeds in the summer months as they grow so fast producing high yields of top quality forage.

I was able to attend an Eblex/DairyCo Lucerne Study Tour to France in the summer of 2013 and all the benefits of the crop were highlighted again.

When you consider these massive benefits to our soil and farmers' pockets it amazes me that they aren't grown on most farms in the UK.

Lucerne growing in France

Red clover growing at Keythorpe

Chicory and plantain are very nutritious, deep rooting herbs that are able to mobilise high levels of mineral from deep within the soil, growing high mineral dense feed which compliment grass swards well, offering mid-season growth due to their drought tolerance. *(See picture on next page)*

Plaintain, chicory and clover growing at the One Farm, Massey University, New Zealand

Some farmers were concerned with the amount of seed produced by the plantain and how this would affect the sward density in the future.

See picture overleaf of sward with high density of plaintain.

Sheep's parsley and yarrow are two other herbs that are very mineral-dense but I did not see them grown that much on farm.

Grass swards can usually meet the stock's requirements in terms of energy and protein but are often lacking in micro nutrients and the use of herbs can dramatically improve the nutrient density of the sward, thus improving animal health and performance.

Sward with high density of plaintain near Hamilton (*Dairy NZ)*

9.2. Grasses

Grasses tend to have most of their roots in the upper layers of soil and, when fed with soluble fertiliser, they will tend to be very shallow, thus increasing the plant's risk to drought and reducing the mineral density of the feed.

Tall fescue, meadow fescue, cocksfoot and smooth meadow grass are some of the deepest and largest root mass grasses but are not so common due to their quality in terms of D value (digestibility) and ME, but they do have the potential to be more nutrient/mineral dense due to their rooting depth.

9.2.i. Brent Stirling – Cropmark Seeds, New Zealand

I met up with Brent at Darfield in Canterbury to see what Cropmark and a progressive plant breeding programme had to offer the livestock farmer in the future. Having grown some of their festulolium matrix (a ryegrass x meadow fescue) on a conventional farm which manages to achieve good results, I was keen to meet the breeder.

Their breeding programme has an emphasis on delivering inter-species crosses involving ryegrasses, meadow fescues and tall fescues that capitalise on the best traits of each parent plant species.

Brent with senior plant breeder in meadow fescue trial plots

This in turn allows totally unique pasture varieties to be created with performance improvements over traditional varieties.

They run a traditional breeding programme for ryegrasses, tall fescues, meadow fescues, cocksfoot and clovers as well.

The company also has a highly innovative and intensive endophyte programme focussed on developing novel endophytes to incorporate into varieties, improving insect pest resistance without negative impacts on livestock performance.

We met with one of the grass breeders and talked about the potential of increasing root mass and improving digestibility and yield. Having been pleased with the matrix, I have now planted a new variety, *festulolium revolution*, and am looking to grow some Ultra in future.

Festulolium growing in Denmark

At the moment, endophytes are not allowed to be incorporated into seed grown in the UK. However, I believe this is technology that should seriously be assessed and if an endophyte could be produced to reduce wireworm attack or even slug damage to clover, this could have a very positive impact on our industry.

9.3. Cover crops/green manures

Cover crops have a massive potential to capture sunlight and to maintain a feed source to the biology in the soil, so keeping it alive and multiplying. We should aim to keep land growing plants at all times to maximise output.

On farms in the UK we often rush to plant the next crop or leave bare land when actually, between maize for instance, it would be far more productive to plant a cover crop to mop up available nutrients, multiply these nutrients using the energy of the sun, and then return them to soil to feed the biology so making more nutrients available for the next crop.

Cover crops can also significantly improve the soil structure, drainage and workability, so reducing cultivations required. Some crops like fodder radish can also have a bio-fumigation effect so reducing pests in the soil prior to planting crops like beet and vegetables.

I am no authority on cover crops but, on my travels, it was evident that many different types of plants can be used very effectively to improve soil structure, fix nitrogen, mobilize P + K, increase organic matter, or bio-fumigate the soil. It all depends on what you are trying to achieve – what crop was last grown, what timescale you have, the time of year and the requirement for the next crop.

9.3.i. Garry Zimmer, Otter Creek Farm, Wisconsin

I visited Garry Zimmer in Wisconsin, USA where he farms with his family on their 1,400+ acre Otter Creek Organic Farm, farming crops, beef and dairy cows. Garry is also President of Midweston Bio Ag that he set up in 1985 with his consultants, working with and advising thousands of farmers worldwide on biological farming methods.

Garry Zimmer standing in lucerne about to be ploughed in prior to growing corn – his home farm in the background.

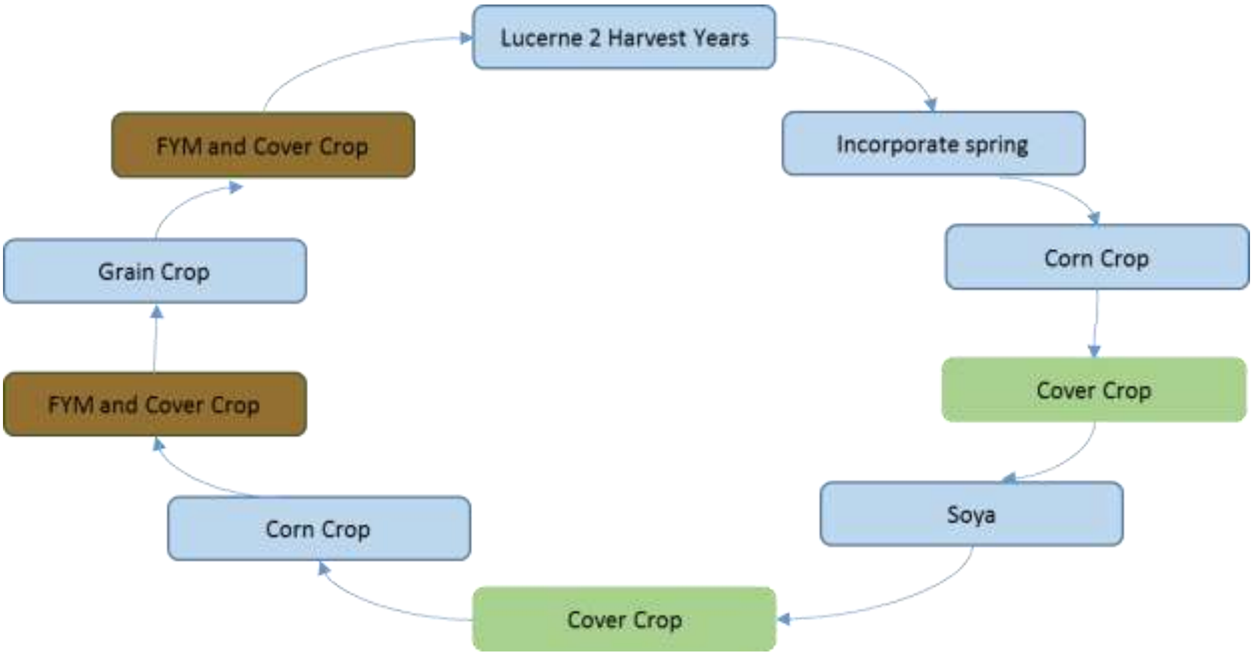
It was here that I saw the true potential of what organic biological farming can offer to sustainable world food production with the use of excellent soil and crop management. Garry and his family were improving soils, producing high integrity, nutrient-dense food and out-performing chemical agriculture.

Garry had adopted a quick rotation and used cover crops at every opportunity. He loved winter rye and spring oats that were excellent cover crops. They grew quickly with a large root mass, mobilizing p + k in the soil, protecting the soil biology through the winter and were easily incorporated back to the soil.

Cover crop of winter oats – on left hand side of picture: after maize. On right hand side: after soy.

Winter rye was planted after soya and corn. After soya they used any available nitrogen that would then be made available to the next corn crop, and after corn they would provide a blanket to protect the biology through the winter and hold any available nutrients that would otherwise be leached away. If Garry was unable to plant a winter rye he would apply manure and then plant a spring oat that would capture the available nutrient from the manure and then be incorporated back into the soil after 6-10 weeks to feed the biology and give of Co^2 for the corn or soya crop.

Garry's rotations varied, but between every main crop there was a cover crop: for example *(in chart on next page)* main crops are in blue, cover crops are in green and brown



Garry said : *"We must feed and protect the biology at all times".*

With so many cover crops being grown and large root mass crops, the soil was really friable. Garry often used a rotavator to incorporate his cover crops. He preferred not to disturb the middle zone of the soil where root channels and a lot of the soil's biology lived but worked in the top 3 inches and then used a sub-soiler, if required, for the lower profile. He was not afraid of the plough and, if he had a large amount of organic matter to incorporate,used a plough when it was required.

10.0. Plant fertilisers - keeping our soils live

In the UK with our present short winter-crop arable rotations very little organic matter or plant residue is incorporated back into our soils; and if it is, the majority of the CO^2 realeased from the breakdown of this organic matter is lost to the atmosphere because the autumn sown crops are growing very slowly with a small leaf canopy which is unable to capture the CO^2 released.

Co^2 is the most limiting factor for plant growth. All plants breath through stomata on the underside of the leaf so it is vital that the soil is giving off CO^2.

Co^2 is released through aerobic organisms breaking down organic matter so it's important to be pro-active in building soil organic matter at all times. This can be by applying FYM, slurry or compost (a living fertiliser), leaving crop residues in the field. or growing cover crops to be incorporated back into the soil.

One of the most effective ways to build soil organic matter is to grow diverse swards to a mature state and them mob-stock the crop, allowing 25% + of the crop to be trampled in.

One of the most effective ways to build soil organic matter is to grow diverse swards to a mature state and them mob-stock the crop, allowing 25% + of the crop to be trampled in.

This has a threefold effect:

- When the crop is grazed at a mature stage the plants will have exuded large amounts of exudate energy back through the roots and into the soil feeding the soil biology.
- The livestock eating the crop will then return digested plants and nutrient back to the soil as manure and urine.
- The 25% + of the crop that is trampled back into the soil is immediately available for the soil organisms to start breaking it down. So, although regrowth can initially be slow from this mature crop, once green, the growth can be rapid due to the amount of CO^2 being released from the soil.

I visited a mob-stocking farm in Denmark – it was a project in conjunction with the Savory Institute.

I saw 500 head of organic dairy steers from three farms grazing as one mob, with ages ranging from 4 months to 24 months – all with their horns still on?? and were being moved twice a day onto a new 0.75 of a hectare.

They were achieving 0.64 kg of liveweight gain/day but this varied greatly depending on the age of stock and the time of year. From 4 months they have no concentrate, only grass/legume based forage, so through the winter it was a silage/haylage mix to appetite.

Although carcase quality was not high, a premium was being achieved due to the organic and pasture fed status. Work was ongoing to achieve a premium for the Savory rearing method.

When I visited the farm they were in their second grazing season but were adamant dry matter yields had increased – the swards were becoming far denser and liveweight gains were improving all the time.

Mob grazed dairy steers - with horns left on!!

10.1. Composting

Dairy farmers usually have large amounts of manure and effluent on farm which are often under-utilised. These nutrients if properly managed can significantly reduce input costs, grow organic matter and increase soil biology.

Converting effluent and manure into compost changes the form of the nutrients in the material making them less volatile and leachable but more plant-available, so more nutrient is used for growth by the plants.

On-farm composting enables other nutrients to be bought in, mixed and composted prior to applying on farm.

Bulky sources of carbon such as wood chip, straw and green waste can seriously increase your volume but **you can also add minerals such as calcium, phosphorus and trace minerals**. By adding them to the compost you are effectively chelating the minerals, binding them to organic matter and making them more plant-available and less leachable; which means much less weight of compost material has to be applied than raw manure to get the same amout of plant growth.

Results have shown that the amount of compost required to get the same results as raw manure is reduced by as much as 90%.

It was very apparent that by spending time making quality innoculants, you could then multiply this initial quantity of innoculants rapidly by adding them to muck heaps - and even spreading them in sheds prior to mucking out.

This is an area where I can see a massive benefit to my farm and will be working hard on in the future.

10.2. Organic foliar sprays

Organic foliar sprays were being used very successfully on a number of farms I visited; to increase dry matter yields, the mineral density of the plants grown, and target deficiencies shown up by tissue tests.

As I said earlier, to rectify your base saturation levels in the soil takes time and money but are important to be worked on. In the mean time, crops still need to be grown and this is where foliar mineral sprays/solutions should be used to target deficiencies in the plants and stimulate soil biology, often using energy sources such as molasses.

Tissue analyses are a good indicator of the mineral density of your crops and ultimately how your soil is working.

To buy bespoke foliar sprays can be expensive but, if these can be made on farm and spread as a solution, especially if the mineral is chelated first, this can be a very good way to target deficiencies.

Jeff Williams in New Zealand was using the "tow and fert" system very effectively to grow high quantities of dry matter with good mineral integrity, which was reflected not only in the quality of his crops but also the health of his cows.

I have started to use foliar suspensions on farm. It is early days and to date we are seeing a positive response; but I need to take more tissue samples to build a clearer picture of the impact the foliar sprays are having on the nutrient density of the crops grown, and to ensure I am applying appropriate mineral and energy.

Foliar sprays can also be an opportunity to reinforce the biological system; coating the leaves in the good biology and so, by competitive exclusion, won't allow disease and pest to attack.

These foliar sprays are commonly known as compost tea which is made by adding good compost to water and an energy source. Again, this can be fortified with mineral and trace elements.

10.2.i. Pete Van Dork – Australia

Pete is a dairy farmer in South Victoria with an expanding business taking on more land and increasing cow numbers. When I was there he was in a joint marketing venture with three other farming families who were branding their milk and selling it into local retail markets.

The brand 'Green Pastures' was built around healthy soils, nutritious grass, happy cows and healthy milk.

They had spent a lot of money on their brand and were only just starting to reap the rewards.

This was not an organic business but a biological one. They had reduced chemical fertiliser use by 81% and were now composting on a large scale, feeding natural organic materials back into nurturing their soils and pasture.

Pete Van Dork and Adam Williams NSch admiring windrow of compost in South Victoria

What interested me most on the farm was the composting and fertiliser policy.

Pete bought in wood chip, then mixed cow slurry from his collecting yard – he added calcium, a vital ingredient for the high mag soils, and windrowed it. That was then turned by a contractor every 3 weeks to ensure it was aerated and was maintaining a temperature between 55°c-65°c until it was well broken down, usually after 3 months.

By doing this he was producing a compost very high in carbon and calcium with some additional nutrients from the cow muck. This was then allowed to cool but as there was still heat next to the soil it meant that some of the soil microbes would migrate into the compost inoculating the windrow with positive biology from the soil.

This compost was then applied in early spring at a rate of 2t/acre with a very positive response and he had maintained his grass yields whilst reducing his N use by 80% to 30 kgs N/acre/year.

Pete was very upbeat with what he was achieving and felt he had the best of both worlds: using the compost, nitrogen fertilser and some herbicides and fungicides to control weed and diseases.

Camperdown Compost was the company who were making Pete's compost – they would analyse his raw ingredients on farm and then advise what other products should be added to maximise the nutrients available to the crops he would grow.

With composting you have an opportunity to massively increase the biology by innoculating the compost with some soil from your best field - if this is your aim you will need to monitor temperature and moisture. For instance if you want to increase the mychorhyzal fungi you will need to keep the temperatures lower, around the 35°c mark, and make a lower stack of compost.

10.3. Re gen Ag Fertiliser Course

I attended this course which was held in Hampshire in June 2014.

We were taught how to make starter innoculants and how to multiply soil microbes very rapidly.

In simple terms you need:

A carbon source	straw, woodchip
Innoculant	soil
Nutrient source	FYM slurry
Energy source	molasses

You can then add:

Minerals	rockdust
Vitamins and enzymes	oats

To increase or target specific areas

An example was the Micro-organism Accumulation (which they had named Toccocana)

Which was: leaf mould and leaves
oats
molasses

This was compacted in layers in a 200 litre drum, then sealed and left for 1 month. This was a low temperature fungal-dominated innoculant that could then be multiplied up by using 30 kg of innoculant mixed into /1 t of raw compost.

Toccocana could also be used as a foliar spray, using:

10 kg Toccocana
8 kg molasses
150 litres water/ha

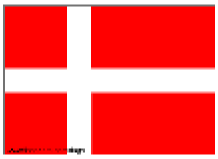
Thus enhancing good biology.

When I attended the course I was critical that this was not farm scale but, in the right conditions, micro-organisms can multiply very quickly and once you have made the initial innoculant, this base material can be divided and then grown on to generate large amounts of top quality compost.

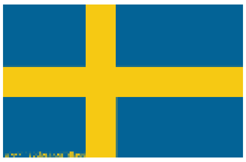
Making a starter inoculant to add to fym to speed and improve composting process

11.0. Discussion

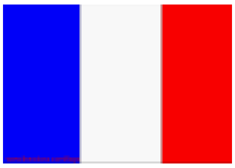
- Kinsey Albrecht soil course.
- Prince of Wales summer school .Sustainable Intensification.GM crops
- Regen Ag fertiliser course organic fertiliser production on farm



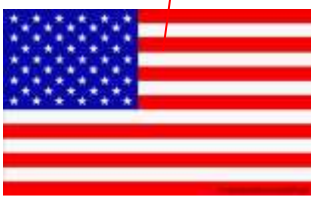
- The Red cow and crossbreeding
- Automation
- Home grown concentrate
- Plant breeding
- Cover crops
- Mob grazing



- The Red cow
- High cost automated systems driving dairy farmers out of business
- Diversity is fundamental to the success of agriculture



- Eblex Lucerne tour conformation of the value of this protein source and highlighted its ability to mobilise mineral from the soil.
- Lucerne breeding programme



- Organic Valley could double output tomorrow if product was available
- Biological farming
- Fast crop rotations
- Cover crops
- Look at impact on farm of 1st generation GM technology

- Growing top soil
- Fertilizer policy on organic farms
- Grazing heights of swards
- Compost a live fertiliser
- Chelating minerals in compost

- Cross bred cow
- High Integrity feed
- Biological farming, Tow and Fert
- Plant diversity
- Grass breeding and endophytes
- Water quality issues excessive urea

The chart on the previous page illustrates where I travelled and what, in particular, I saw in each of the countries visited. So, having travelled to Scandinavia, France, Australasia and the USA. my thoughts are as follows:

- Competitive exclusion using good biology is vital. Chemical agriculture de-waxes the leaf with sprays that not only strip the leaf of its natural oils but usually kills the plant's own leaf biology, leaving a bare leaf very exposed to disease infection.
- When you look at the highest yielding arable farms around the world, as my fellow Nufield Farming Scholar Jake Freestone's report details, you see farmers who respect the soil and plant biology and enhance this and then use chemicals to target specific problems.
- Any word ending in "cide" means "kill": e.g. suicide, homicide, herbicide, pesticide. Herbicides and pesticides are killing either plants or pests in our fields. We cannot employ these products without changing or altering the biological balance within our plants and soils.
- There are times when both herbicides and pesticides are vital for food security but to use them as insurance policies year on year, regardless of disease pressure, will only create disease resistance in the future.
- The use of high levels of soluble fertiliser means that the fertiliser moves into the plant by diffusion i.e. moving from a high concentration to a low concentration so the plant cannot regulate the flow of these very soluble nutrients.

  This causes a mineral inbalance in the plant and when this occurs the plant cells and proteins are not fully formed and at this point the plant's immune systems are compromised so disease and insects attack; insects have the ability to identify and attack stressed plants i.e. Plants with Low Integrity.

11.1. Gylphosate Ready crops

Nowhere in the natural world is land left bare; if moisture is available, plants will always grow and fill in the space.

It is only in agriculture we see large areas of bare land – this was highlighted travelling through Iowa and Minnesota in the USA for 3 hours. Admittedly it was in May so drilling was only just starting but to think nothing had been growing since harvest 7 months ago horrified me.

My fears were justified when I saw how much drainage was necessary on fields which had grown glysophate-ready soya and corn for a number of years. The soil biology was dead or at seriously low levels; the organic matter was being burnt off with chemical and fertiliser; the soils had slumped so badly that farmers were now draining their land for the third time. There were now tile drains about every 4 metres.

As this area had experienced the dust bowl in the 1930s I thought cover crops would have been used extensively to help maintain some biology in the soil, feeding and sheltering it through the harsh winters. But apparently not.

Tile drainage again, trying to rectify poor soil structure

I travelled through these states to visit Dennis Lutteke, an organic dairy and crop farmer – farming 860 acres with 90 cows in milk. His farm was a green oasis amid thousands of acres of corn and soya stubble which had bulldozers pushing soil back up into higher ground as there was no vegetation to hold it and drainage machines were working flat out.

Dennis was growing lucerne, oats, peas, corn and soya. With his rotation and with the use of cover crops he was out-yielding his neighbours and was the only farm I saw with a large new grain silo.

He had recently bought a new John Deere self propelled forager for his 90 cow herd and had a tractor on the front of virtually every implement in his machinery shed. He was also running a flame weeder engineering business - all these were some very telling signs of a farmer making money.

Another interesting fact was that he was achieving 70% conception to first service in his Holstein cows and he put it down to him using cider vinegar that helps prime and tone the cow's uterus.

His neighbours had been growing glyphosate-ready crops for a decade and he had watched their land slump. He took me to a field boundary and showed me where surface water used to run onto his field from his neighbour's; but after 12 years of intensive chemical farming and with a GM soya-corn rotation by his neighbour, the water now ran back from his land onto his neighbour's – a 10" change in height. Both farms were originally high organic matter, black soils. Dennis was building OM while his neighbour was burning his away.

Dennis's comments on GM were that he does trials with wildlife; if you put his organic corn out on the bird table plus some of his neighbour's GM corn the squirrels will eat his corn but won't eat the GM corn - no matter how long you leave it, and they will stop coming to the table. But as soon as he puts his own orn out, the squirrels are back feeding – they just know!

Dennis Lutteke with a handful of his organic corn – which he says the local squirrels prefer

His local markets are growing year on year for this produce and he said there was such a backlash against GM that Monsanto were breeding conventional corn and soya varieties to meet a very fast growing market.

Dennis's comments were echoed by Karl Dalefield of Prairie Creek Seeds saying they had a much larger market for non-GMO seed and it was increasing year on year.

Karl was also adamant that the higher the diversity of a forage sward, the higher the quality of that forage and that cover crops were a fast growing market and were usually sown on to standing crops of corn and soya just before rain.

11.2. Development of Biotechnology

On investigating what 1st generation GM technology has to offer the UK livestock farmer, I have found only negative effects and comments.

Glyphosate has a half life (the length of time taken to lose half its biological activity) in the soil for up to 215 days and up to 63 days in water; so one application of Glyphosate can suppress soil biology for up to13 years before it reaches negligible levels.

Glyphosate will mummify soil biology when used excessively.

Glyphosate will mummify soil biology when used excessively. If soil biology is not functioning, the integrity of the plants we produce will be compromised, which will impact the whole food chain, lowering its status.

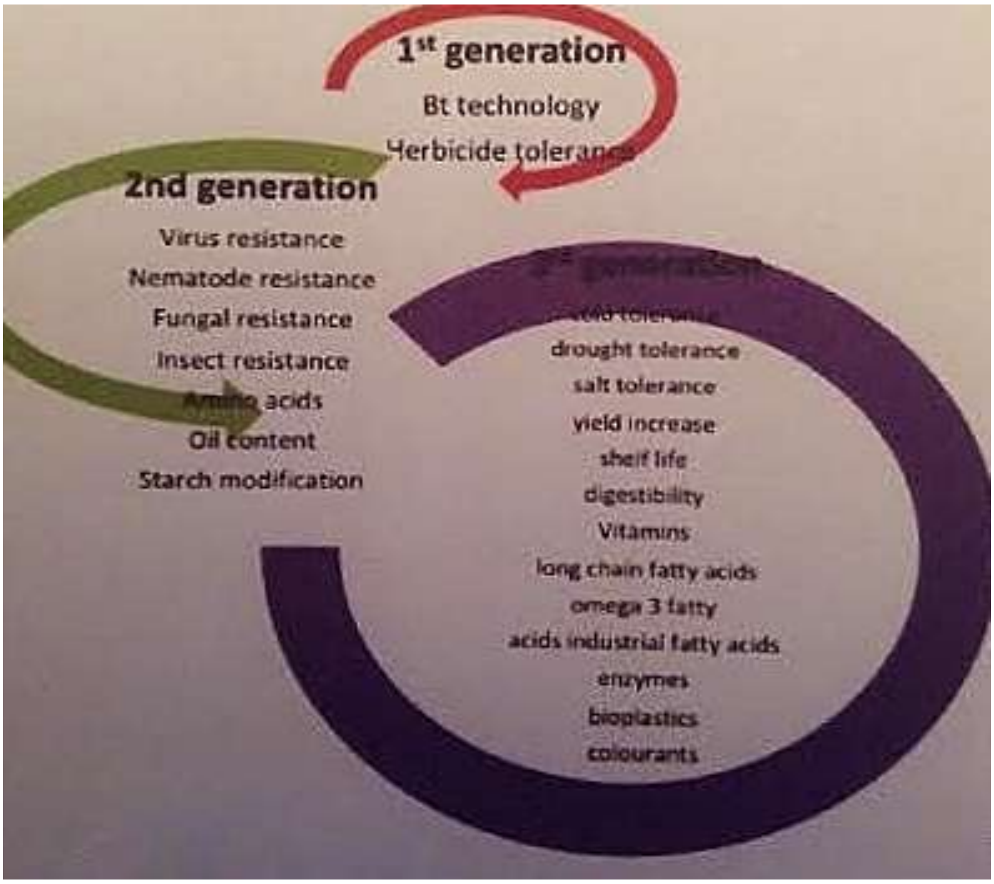
If soil biology is not functioning, our soils will slump, increasing water run off; become compacted and not hold water; and become more reliant on chemical insurance policies.

UK agriculture should not adopt glyphosate-ready crops. We have a big advantage at the moment that we need to maintain, as the world is rapidly waking up to these first generation GM technologies with their problems and limitations.

I have not investigated 2nd and 3rd generation GM technology, but when you look at the list in the table below, setting out what this further technology hopes to achieve (*see next page*):

- Cold tolerance
- Digestibility
- Long chain fatty acids
- Omega 8 fatty acids
- Vitamins

these could all have a very beneficial effect on the UK livestock sector as long as robust research and sound testing by independent bodies is carried out and is not company-driven to make fast money.



For further explanation please refer to GMO Myths and Truths: see
http://earthopensource.org/index.php/reports/gmo-myths-and-truths

12.0. Conclusions

Sustainable Milk Production:

1. Is and always will be a moving target.
2. Looks very different around the world.
3. The higher the cost base in the system, the higher the financial risk to the business.
4. The quality and integrity of what we feed our cows is vital for the health and productivity and ultimately the profitability of our business.
5. Our soils are one of our most valuable assets, that are often overlooked or mismanaged; knowing your Base Saturation levels is the starting point.
6. The higher the soil biology count the stronger the mineral transfer from the soil to the plants and the feed quality will increase.
7. Plants grown in high biological soils are less prone to disease and pest attack.
8. As livestock farmers we have an opportunity (and an inbuilt advantage via the manure produced) to significantly multiply soil microbes with the use of live fertilisers, FYM, compost and foliar feeds.
9. Plant diversity will increase resilience in our soils and farming systems.
10. The over-supply and application of highly soluble fertilisers are shutting down the soil biology and are burning off soil carbon reserves causing imbalances in soils, and the immune systems in plants are challenged so there is a higher requirement for herbicide and pesticide use.
11. 1st generation GM technology only has negative effects for the UK livestock sector.
12. The UK has an advantage that is not yet realised and, as part of the world's population demands higher integrity and therefore non-GM food, we can produce this the UK.
13. We cannot feed the world on "empty calories".
14. Organic agriculture has its limitations with very strict input controls.
15. With a better understanding of our soils' biology and focusing on diversity both in our soils and cropping plans, we have the opportunity to improve the integrity of the food we produce and have a positive impact on animal and human health.
16. Biological Farming is the Future.

13.0. Recommendations

1. Know the Base Saturation Levels in your soils.

2. Enhance soil biology as a priority.

3. Use plant diversity to enhance forage and feed quality and build resilience.

4. Make maximum use of on-farm manures by composting and adding minerals which will chelate to make a live mineral-dense fertiliser.

5. Fertiliser plans should be produced from your knowledge of the base saturation levels in your soil.

6. Maximise home produced feed.

7. Question the integrity of any bought-in feed.

8. Be vocal and help to build links with UK arable farmers to grow the UK livestock's home grown protein source and influence the decision on 1st generation GM technology crops being grown in the UK.

14.0. What is, and what will, happen on farm as a result of my study tour

On Farm

- Establish the Base Saturation Levels of our soils and, as a result, create a long term fertiliser policy to address our weaknesses on farm.
- Utilise our farm slurry and manure with composting, adding additional carbon sources and looking to chelate some of the additional minerals that are required, plus using live innoculants to grow our soil biology.
- Build plant diversity: grow a lot more grass types in our swards, optimise our clover using higher levels and different species, introduce deep rooting herbs.
- Assess and trial different grazing strategies to optimise plant growth, mineral transfer and cow performance.
- Establish cover crops at every opportunity.
- Grow diverse whole crops with the aim to combine and heat treat them as our concentrate source, but ensile them if the weather is against us.

Off Farm

- Promote the massive benefits that increasing Soil Biology and Plant Diversity have on improving the integrity of the food produced on all farms.
- Aiming to set up a soil conference in March 2015, covering all topics in my study.
- Be vocal and help build links with UK arable farmers to create the UK livestock protein market and influence the decision on 1st generation GM technology crops being grown in the UK.

Wil Armitage

15.0. Executive Summary

As UK dairy farmers adapt and learn to ride the peaks and troughs of volatile milk prices their business models need to be robust and assets on farm must be optimised.

Land is the largest asset managed by individual farmers and the decisions made in the field affect the quantity and quality of the feed produced.

Having farmed both conventionally and organically for 30 years I have seen the benefits and limitations for both systems. The biggest change I have noticed on my farm since converting to organic is the soil structure and the amount of soil biology. However production has now plateaued and I feel we are only running at 65-70% of the land's potential output.

The objectives of my tour were to increase dry matter and crop yields with the adoption of excellent soil and crop management; to look at protein sources being fed to dairy cows; and see if here in the UK we could adopt and grow any new protein feeds.

The final part of my study was to investigate what the impact would be on UK dairy cows of adopting and growing first generation GM technology crops.

I visited Denmark, Sweden, France, Australia, New Zealand and USA.

I did not realise at the start of my study that all my objectives had a common denominator: that being the soil beneath our feet.

I was well aware that I could increase crop yields with soil management but did not appreciate the vital links between soil biology and the mineral transfer from the soil to the plants and animals; and how the integrity of the plants produced affects the health, immune status and ultimately the longevity of our cows.

Whilst looking at protein sources it became apparent that although crude protein is an indicator it is a very blunt instrument – as is ME – and we should revaluate these systems for feeding cows.

On farm we have the opportunity to greatly increase the quality of the feed we produce and reduce anti nutritive components by growing nutrient-dense feed with a balanced mineral profile. But to achieve this we must firstly establish the Base Saturation Levels in our soils and then enhance the soil biology to ensure the mineral transfer is high. An over-supply of soluble fertiliser or continual use of chemical sprays will suppress soil biology, so reducing the mineral transfer to the feed produced.

As a result of my findings and establishing the BSL in our soils, I am now looking at fertiliser programmes on both my organic and conventional farms to improve feed quality.

I aim to feed and enhance soil biology allowing plants to exude more energy back into the soil; use plant diversity to help mobilise soil minerals; use cover crops where I can, and use slurry and FYM to make the fertilisers rapidly multiply soil micros that can then be applied at a greatly reduced rate compared to the base material.

16.0. Thanks and Acknowledgments

Firstly I must thank the Nuffield Farming Scholarships Trust and my sponsors the John Longwill Trust for this amazing experience. On application for a Scholarship I had underestimated not only the pressure but also the massive benefits it would bring both to me and to my businesses.

It would not have been possible without the positive support from my business partners: Peter Dixon Smith at Keythorpe, and Tony Evans and Peter and Cheryl Holmes at Manor Farm, plus the staff on both farms, especially Jason Frow and Andrew Camble.

On my study around many parts of the world I attended courses and conferences, visited universities, plant breeding companies, research stations, seed houses, certification bodies, dairy equipment manufacturers, biotechnology producers, research farms, dairy genetics companies and milk processors. I thank them all for the time, hospitality and knowledge that were shared with me.

As a passionate dairy farmer who enjoys working with cows and on the land I send a massive thank you to all the farms, farmers and hosts I visited, and especially for sharing your knowledge and experience with me and offering a bed for the night. I hope that this report is of some use to those farmers and friends whom I have made whilst on my Nuffield Farming study.

Finally I must thank my wife Michaela who has been a massive support behind the scene for years, and to daughter Jessica and son Giles who have kept her sane and who have fed calves, driven tractors, moved stock, and kicked me when I needed it, and kept a smile on my face.

Thanks to all.

Wil