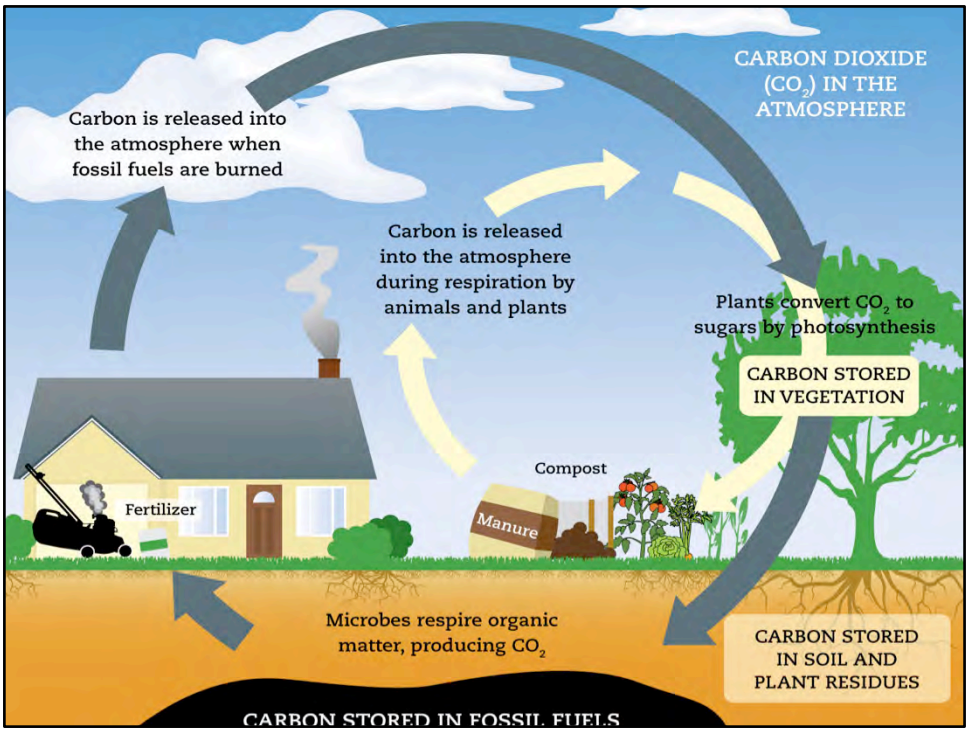
Nature likes carbon in the soil, since man started cultivating the soil millions of tonnes of carbon has been released into the atmosphere. Carbon starts out as a gas and through the processes of photosynthesis, plant growth and microbial action ends up as carbon in the soil.

Soil carbon enables biology, adequate carbon plus active diverse biology equals a healthy soil.



The carbon cycle or as I would prefer the carbon flow, Allan Lauder wrote a book called “Carbon Grazing” which I think should form the corner stone of the grazing industries BMP.

Carbon is always moving through the landscape and depending which path it takes will determine how long it takes to get from the gas it starts out as to return to that gas again.

In Agriculture we have been focused on organic carbon in the soil which is the longer term storage portion of carbon flows, what we have largely missed is the importance of carbon flows, short term carbon such as organic matter, plant tissue alive and dead, biology ect.

Our focus should be on the carbon flows, the secret is to have more carbon flowing in than out and that needs to happen 100% of the time if we are to build carbon instead of losing it.

Soil hydrologists classify fresh water as either blue or green, blue water is all the visible fresh water, rivers, lakes and includes water in under ground aquifers. Green water is held in plants and soil. Blue water represents about 39% of total precipitation and green water the other 61%.

One percent increase in organic carbon would store an extra 250 000 litres per hectare of green water x that by my farm size of just 150 hectares means an extra 37 500 000 litres of water held on my farm every time there is a run off event. Expand that out and its not hard to understand why flooding events seem to be getting worse over time, simply put not as much is going into the soil.

How do farmers make Carbon ?

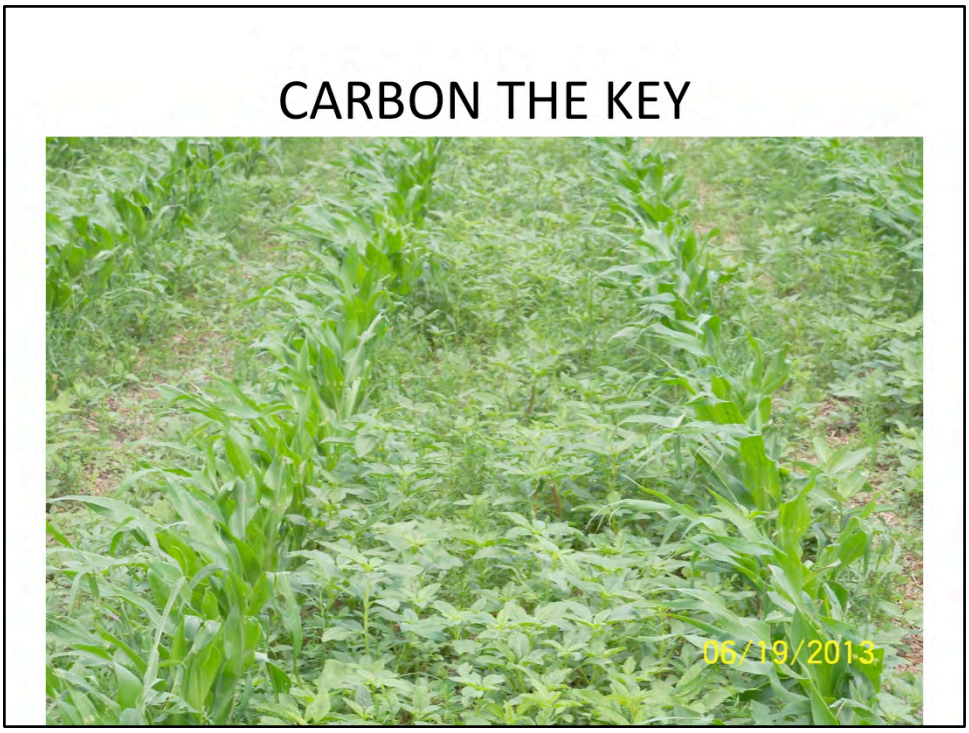
Sunlight + Water

Both are FREE "Bags and Bottles" are not

Farm in a way that maximizes the amount of sunlight and water you collect.

Aim = improvement of SOM, biology, biomass, growing carbon, catching maximum water and sunlight to turn into either a cash crop or soil organic matter for future cash crops

Managing the things that we can is all important, we cant determine how much rain falls on our farm be we can influence how much of that ends up in our soil, plant roots create holes in the soil for air and water infiltration.
We cant determine how much sunlight we will get in a growing season but we certainly can influence how much of that sunlight we capture with more and diverse foliage to capture light through adopting strategies such as multi species plantings which gives you different shaped leaves at different angles to maximise sunlight capture.



Looks like a field of weeds I hear you say, look at it this way. How does carbon get from the air into the soil, through plant photosynthesis and soil biological process. Would this field create more soil carbon if the plants between the rows of corn were not there, how could it with less green leaves.

Plant diversity heals soil, plants take carbon dioxide from the air use part of it to grow themselves and the rest they give off as exudates to the soil food web, this is their primary food source. They in turn build soil aggregates which improves infiltration, increases nutrient cycling.
Degraded soils are unlikely capable of converting that carbon to humus, thus the soil organic matter does not increase.

On my Nuffield Scholarship I visited this farm in Nebraska USA, what we are looking at here is a multi species intercrop planted on the same day as the corn. No doubt your first reaction would be concern as to the amount of nutrient and water that the other plants are taking from the corn. While your soil carbons are low it will be an issue and in the first couple of years of doing this you will need more water.

However after that they will actually put back more of both than they can rob. How you ask, nutrient cycling, when a plant takes up minerals they stay in that plant and if its left on the field when that plant dies it releases those nutrients back into the soil

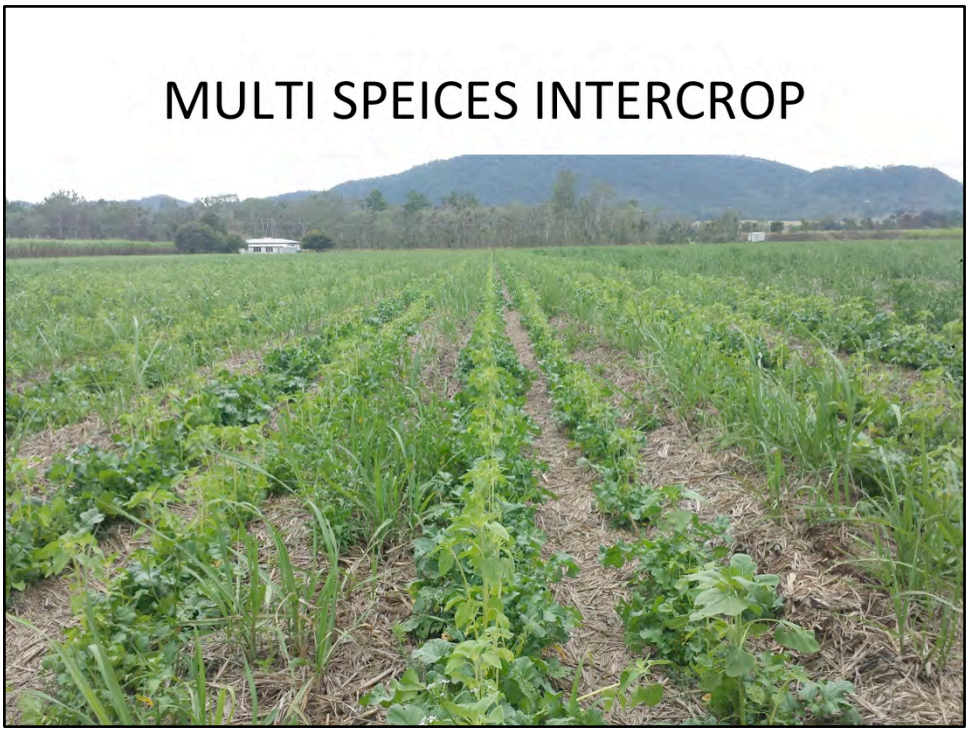
SAME FIELD NO HERBICDE

Same field one month later. Crop yielded 194 bushel per acre which is about 12 tonnes to the hectare, fully irrigated, previous crop soybeans, no nitrogen applied to corn crop.

Diversity of plant species creates an environment for a diverse range of biology, different biology perform different roles in the soil and like different plants as hosts.

In our soils the only biology left will be the ones that like sugar cane, and it is unlikely that there is a broad enough range of biology left to perform all the functions in the soil that is necessary to have a healthy soil.

I think that inter cropping can work in sugar cane, selection of the most suitable plants will take time and effort. There has been some talk of extended fallows with several different crops grown to improve soil health, for us at Mackay that will be difficult because we have so little infrastructure for those other crops, because of the lack of infrastructure a lot of the potential income is lost in extra freight costs.



Bringing the same lessons learned from the US home, this trial is on my farm at Mackay. Eight different plant species planted 600mm apart in-between rows of cane. Second ratoon crop of Q232, cut on the 29/6/2014 yielding 132tph planted to a mix of Sunflower, Vetch, Chickpeas, soybean, Oats, Ryegrass, Radish and Turnip on the 16/7/2014. This trial has three treatments repeated four times, one of the treatments is my farm standard practice so it is the control in this trial. Root and soil samples were taken from the block in May 2014 by Dr Susanne Schmidt university QLD and these samples will provide the base line as this trial goes forward.

The idea here is the same as the corn field in the previous slides, increase plant diversity will increase soil biological diversity, which increases nutrient cycling and carbon capture there by increasing water holding capacity over time as soil organic carbon levels rise. The benefits of increasing soil carbon doesn't stop there with scientific evidence also pointing towards both pest and disease suppression.

Over time I think one of the biggest potential benefits will be an extended ratoon cycle, at the moment the industry is on about a five year cycle if we could make that a ten year cycle through improved soil health those savings alone would more than justify the cost of the seed.

This is what the field looked like just prior to being sprayed and crimp rolled.
The potential benefits that inter cropping offers are many, but the primary goal is to improve soil health. It is long proven that rotation of crop species is beneficial and this is the best way that I see we can introduce more plant species into our mono culture, just rotating with a legume once every five or six years in the fallow will never be enough to maintain soil fertility.

We need to be patient while trying to rebuild our soils, it has taken decades for our soils to run down to the point where we are now and we cannot expect to fix that in one or two seasons. From what I saw in the US they took three years to stop the decline and another three to really start to see improvement.

Plant diversity allows for soil biology diversity, more plants like in the above photo allows more photosynthesis, which increases the potential carbon and other nutrient cycling that will occur.
In this trial I increased soil carbon levels by 15% over three years within the eight species plots.

You may think you could achieve the same effect just by letting what ever weeds want to grow, the problem with that is the lack of diversity as the weeds that are currently growing in our cane fields have adapted to the soil biology that is there over

	Free-living nematodes/200 g soil		
	1 month	3 months	7 months
Nil	705 c	1333 bc	966 bc
4-species mix	3836 a	4111 a	1083 bc
8-species mix	4559 a	4045 a	1499 bc

Interaction table showing the effects of treatment (intercropping with multi-species mixes)

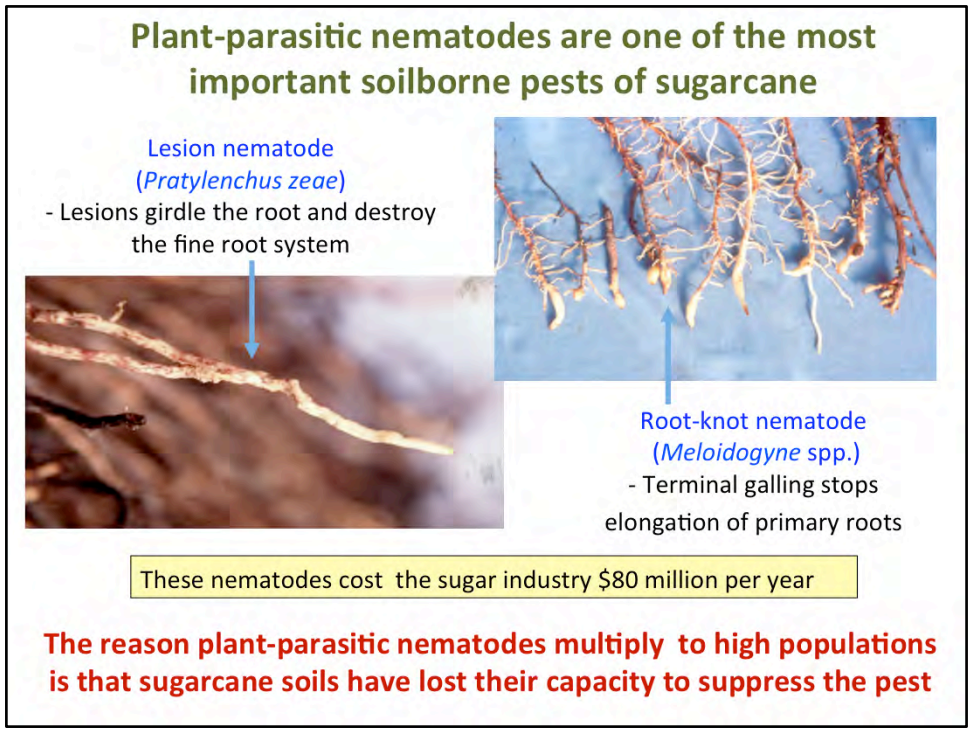
	Nematodes/200 g soil					
	Root-lesion	Root-knot	Spiral	Stunt	Stubby	Dagger
Nil	189 a	5 a	58 a	14 a	29 a	1 b
4-species mix	86 b	34 a	56 a	4 a	63 a	8 a
8-species mix	116 ab	12 a	19 b	3 a	39 a	5 ab

Effects of growing multi-species mixes as an intercrop for three successive years on populations of plant-parasitic nematodes

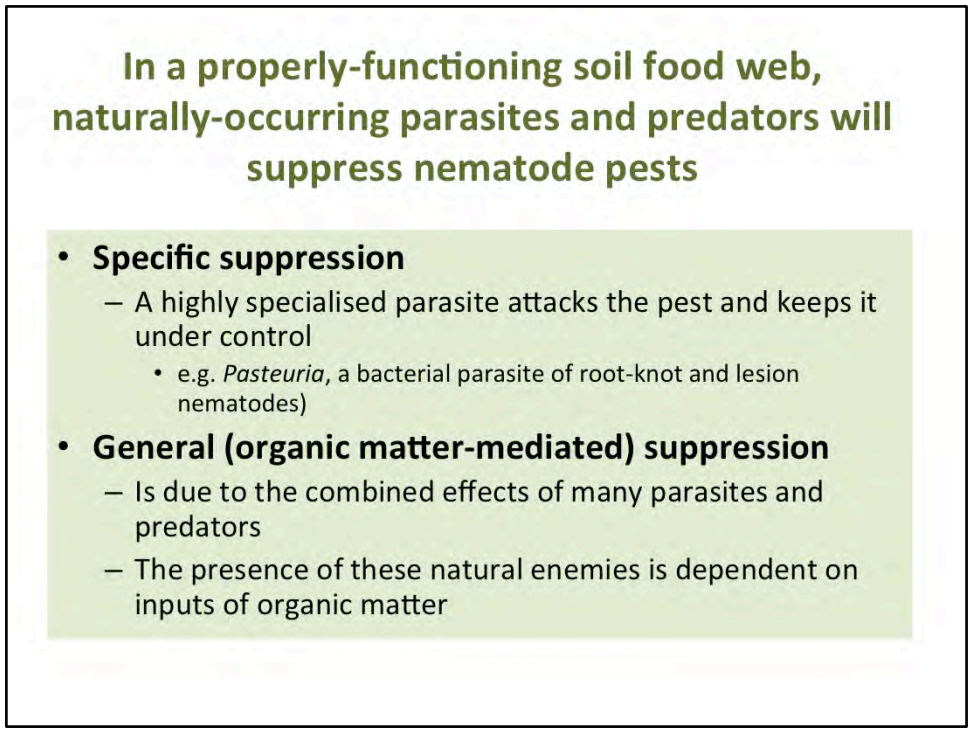
Some of the nematode figures from the same trial plots, work done by Dr Graham Stirling.

The interesting information in this slide is the increase in free living nematode numbers within the inter cropped sections. I had originally set out to wind down the bad nematode numbers however what we found was that the numbers of problem nematodes such as root lesion and root knot didn't change that much however while the intercrop was actively growing and for sometime after it had finished the numbers of free living nematodes were greatly enhanced.

This would have kept those parasitic nematodes in check through predation.



I am sure you are all aware of the damage nematodes cause and the work of Graham Stirling to try and fine strategies to control them. Without doubt they are a huge problem across a broad range of agriculture industries and in the case of the sugar industry we are going to need a range of strategies to combat their effects.

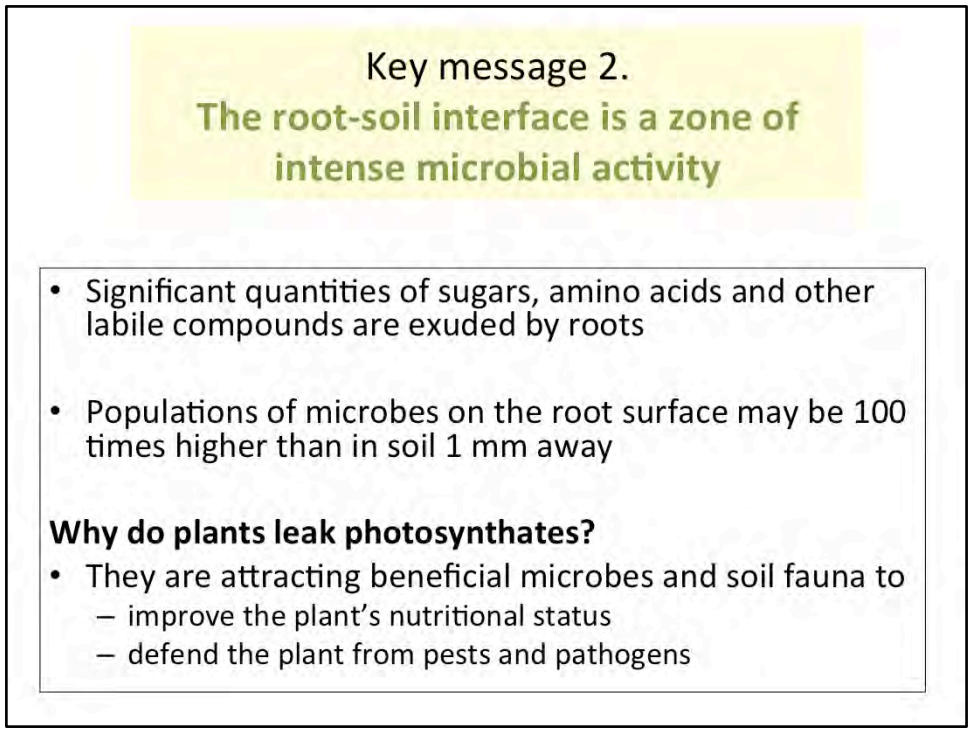


As a farmer I need to adopt a number of strategies to control nematodes and as it turns out those strategies are the same as the principles that need to be adopted to maximise the potential use of the four things I mentioned earlier that we all get for free.

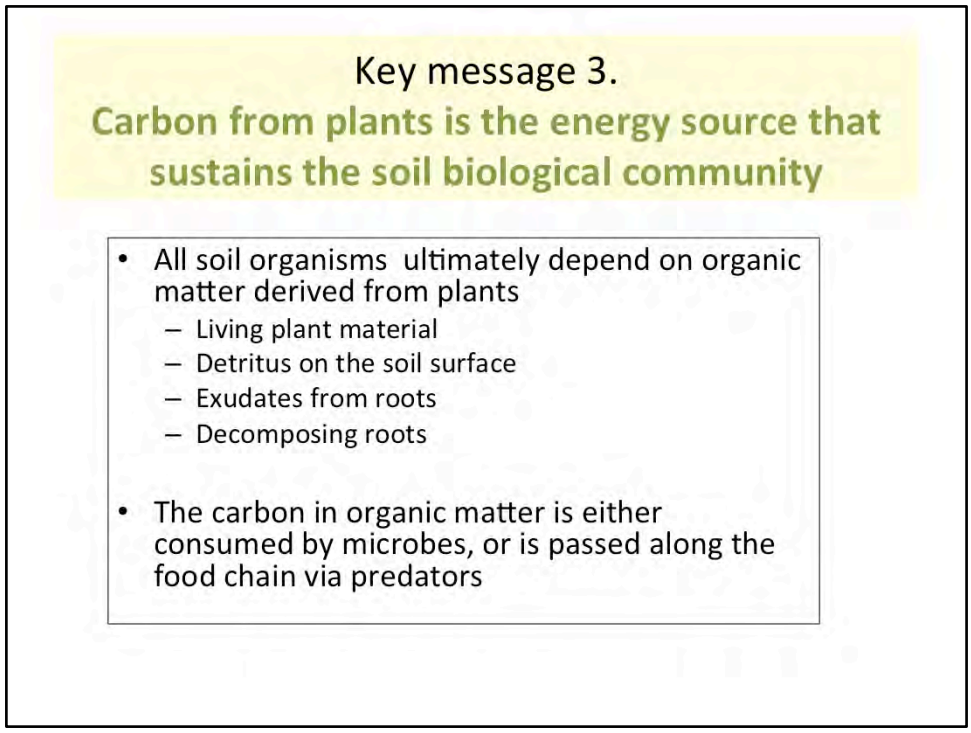
Key message 1.
Soil is the most complex ecosystem on earth

Organism	Approx. numbers per gram of healthy soil
Bacteria	100 million
Actinobacteria	10 million
Fungi	1 million propagules; 2 km of hyphae
Algae	10,000
Protozoa	10,000
Nematodes	50
Many other small animals are also present	
Mesofauna (mites, springtails, symphylans, potworms). Mite populations are often > 100,000 per square metre	
Macrofauna (isopods, centipedes, millipedes, spiders, beetles, termites, ants, earthworms)	

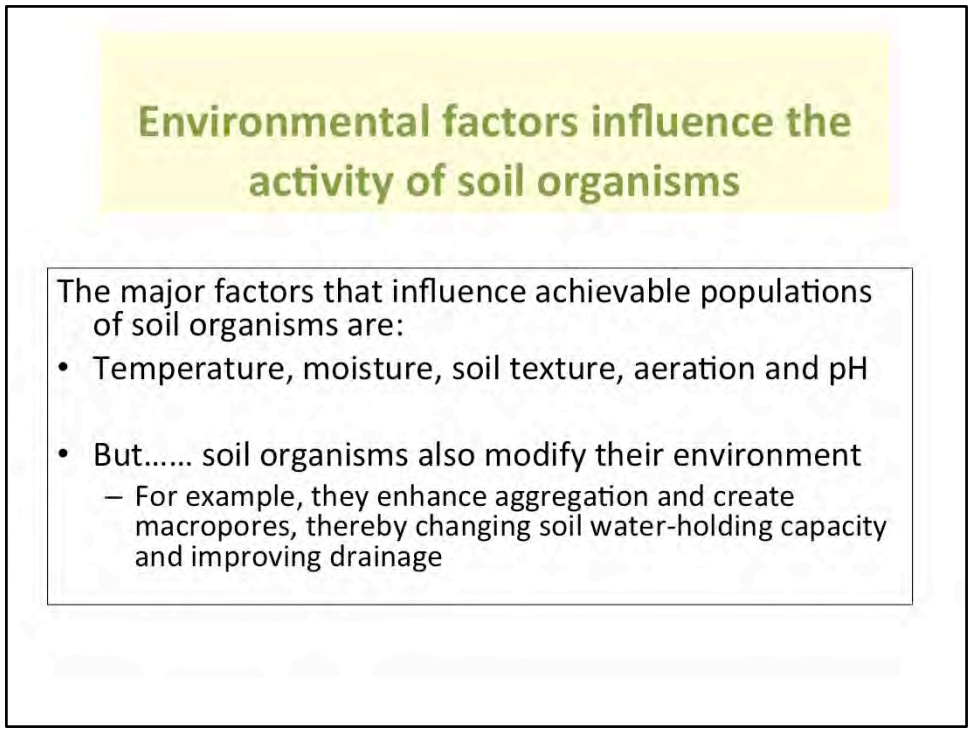
Since starting on my journey of discovery I have become aware that the soil is an ecosystem and a highly complex one and at this point in time most soil biologists would agree with me stating that “we know enough about soil biology to know that we know stuff all”



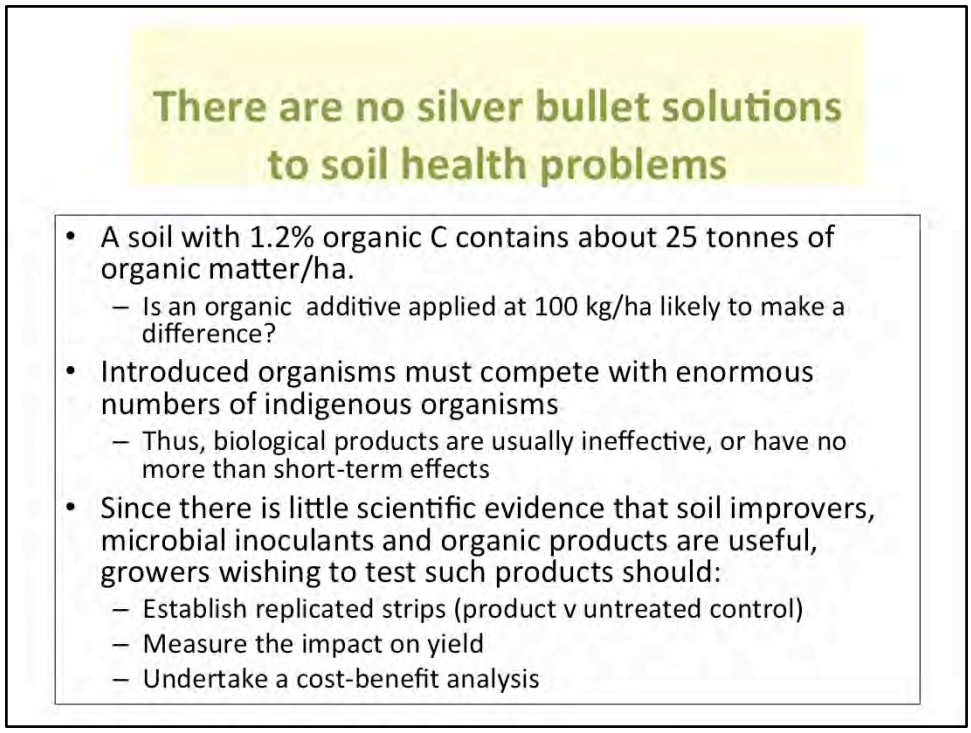
One of the principles of Regenerative Agriculture is to always have a living root in the soil and this slide explains why that is so important.



Another key to RA is always having organic cover on the soil, we all appreciate how important that is in times of high rainfall to prevent erosion, but don't forget it is just as important from a biological point of view when times are hot and dry, cover on the soil regulates soil temperature.



As farmers we have influence over all of the environmental factors that influence soil organisms and we need to stop and think about that next action we are about to perform in our field and ask ourselves if what we are about to do is going to adversely affect our soil biology, more than likely it will so how can we mitigate that or can we achieve the same end game with a more biology friendly action.

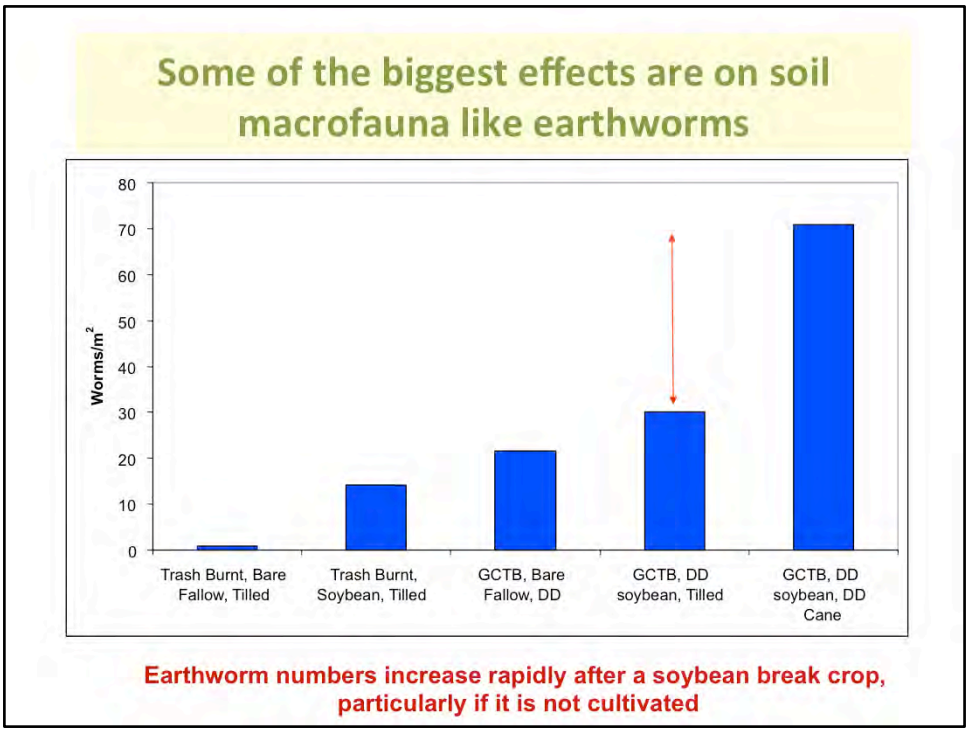


Over the last ten years I have used a multitude of soil improvers, microbial inoculants and organic products and as yet I have not been able to replicate any benefits and in most cases I haven't seen any benefit in the first application either.

However the sugar cane mono-culture we have created over the last few decades would be a highly challenging environment for any introduced biology, across the industry we have very high levels of compaction, so very limited air and water infiltration, very acidic conditions with 93% of soil samples in the central district having a pH below 6.2 (Incitec Pivot figures from almost 5000 samples taken) 90% of soil tests in the central district showing Organic carbon levels of less than 1.6%

So I have come to the conclusion I need to first create a more friendly environment for the biology, hence the need for plant diversity. All plants have symbiotic relationships with various forms of soil biology, legumes and Rhizobium bacteria, sunflowers are known to be highly mycorrhizal being a very good host of mycorrhizal fungi where's all of those plants in the brassica family are the exact opposite and are extremely poor host of mycorrhizal fungi.

This is how nature is able to so successful in perpetuity without any input from us, plant diversity enables biological diversity which enables nutrient cycling and so the cycle of life continues.

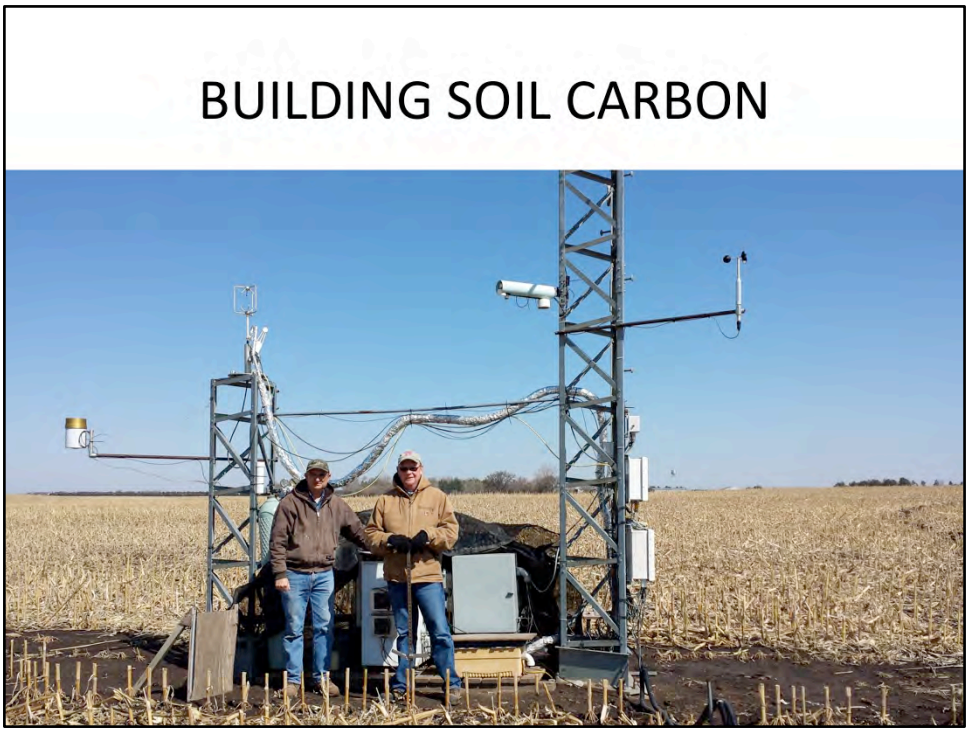


Another key principle of RA, minimise mechanical soil disturbance, hence the success of no-till in the grains industry, but even that success has reached a plattoue with the recognition that further plant diversity through rotation is needed to achieve continued improvements in soil health.

The Melsetar group near Cape Town South Africa grow 7 different varieties of pears and 12 different apple varieties. Exporting all over the world but mostly to Europe. Directly employing 1500 people and indirectly another 2400 in associated business's.
Interesting micro climate in Elgin valley farms against mountains on sea ward side of valley twice the rain more cloudy days much cooler. More rain has leached out nutrient's, ph. of 3 up to 60 tonnes per hectare of lime applied not only to correct ph. but to raise calcium levels in the soil.

Calcium is a key component in attaining soil health, it does much more than just correct ph. on acidic soils, it also allows the uptake of other minerals in the plant and is an integral part of the pumping mechanism of cell membranes, moving minerals into plant cells and most importantly and most forgotten about it stimulates microbial activity.
Nutrient balancing is key to growing good fruit, and I think this will also be a key point for us to remember while we are striving to improve our productivity.
Boron and calcium have a syigistic relationship if there isn't enough available boron the plant will not be able to fully utilise available calcium. Boron is an anion and is mostly held in the soil by organic carbon. So low organic carbon quite often means low boron.

I have found my levels to be very low in both soil and leaf tests, and I think a lot of

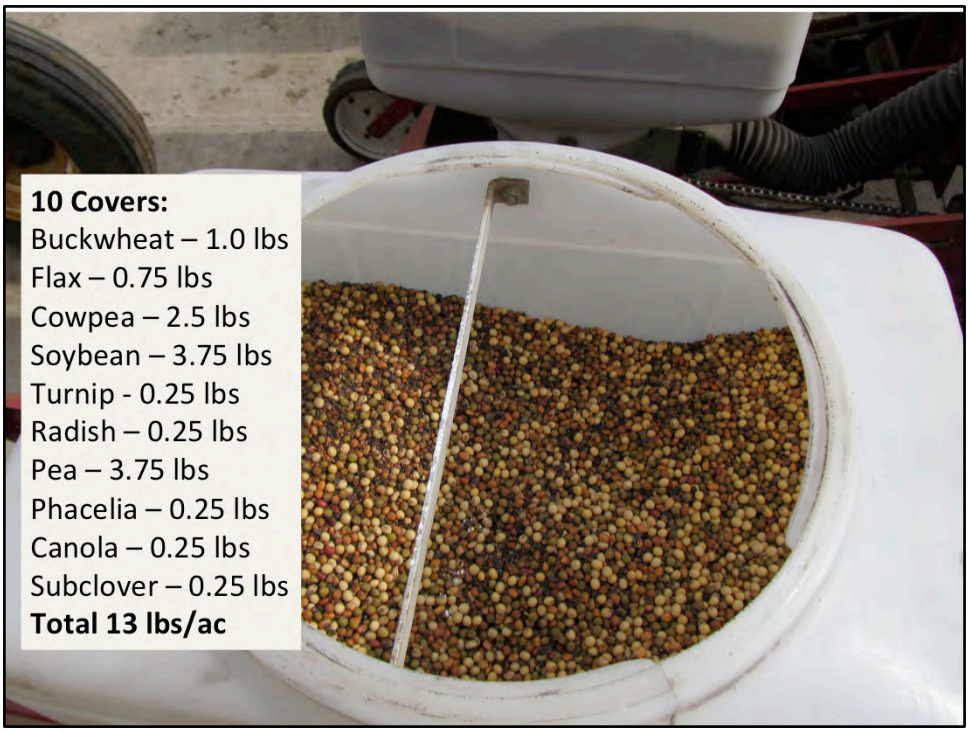


I saw several trials trying to build soil carbon, this one is the longest running (14 years) and the most extensive when it comes to monitoring. Financed by the US Department of Energy and run by Professor Andy Suyker of the University of Nebraska, School of Natural Resources. The trial is spread over three sites on 450 acres two sites are fully irrigated with centre pivots one site is dry land, two sites are a corn and soybean rotation one fully cultivated one no till the third site which is the dry land site is a corn, soybean and alfalfa rotation.
The dry land site is the only one that has sequestered carbon over the life of the project, when the project first started alfalfa was not in the rotation it was added the second time the project received funding so because it has not been going as long they are unsure as where it would be. However the one thing they are sure of is the fact that it is the only site out of the three that has increased the levels of carbon in the soil.
These site are very comprehensibly monitored with a number of measurements taken every second and generating 18 megabytes of data per day.

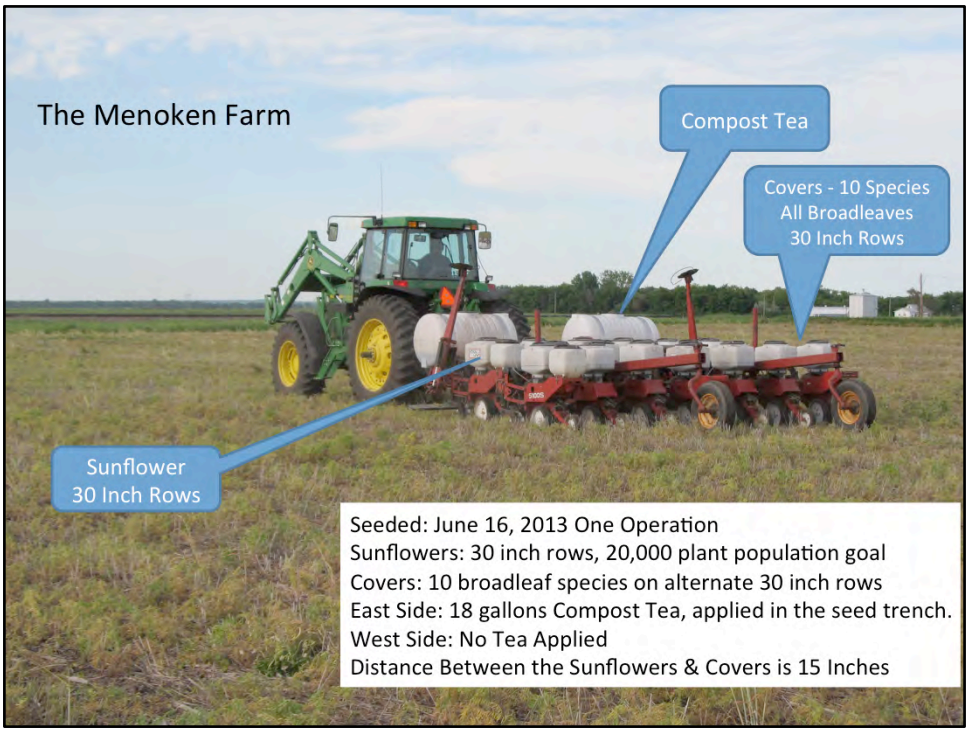
The key point that needs to be taken from this trial and backed up by several other trials I have seen is that perennial grasses play a very important role in carbon sequestration. The addition of animals to a rotation including perennial grasses seems to speed up the process of fixing carbon in the soil.

Polyculture the answer to how we can build soil carbon. Meet Gabe Brown on his farm near Bismarck ND biological farmer for the last 15 years. He has not used synthetic nitrogen in more than 12 years and his corn and soybean yields are still well above his county average.
How does he do it, 2000 acres cropping, 1500 acres pasture, 20% of cropping country devoted to up to 20 different specie cover crop that is mobbed grazed with cattle. Electric fence used to control mobs of up to 800 head on an acre at a time, with the cattle shifted every two to three hours during daylight hours.
What the cattle don't eat they trample and manure the whole area while feeding. If you want to see more find a YouTube clip called "Soil Carbon Cowboys".
The cover crop not only provides nutrient for the following cash crop but also fattens his cattle.
He has more than tripled his soil carbon content in the last ten years with most of his fields now sitting between 5 and 6% organic carbon, the benefits are many, for every 1% rise in organic carbon soil will hold an extra 16.4 litres of plant available water per square metre, nutrient holding capacity is increased, disease and weeds are suppressed mainly due to the crop being healthier.

15 Years ago Gabe was where we are today he came to the realisation that almost everything he made he was giving to the crop protection industry with nothing left for his family or even to pay the bank loans. That is when he decided he had to make



A classic polyculture mix in North Dakota, the mix I need at Mackay will be vastly different.



The seed mix in the last slide being planted

Another example of intercropping, this is a trial on Menoken Farm in north Dakota, Sunflowers planted on 30 inch rows with a 10 species broad leaf only intercrop planted on the same day also on 30 inches. Buckwheat, flax, cowpea, soybean, turnip, radish, pea, phacelia, canola and subclover.

No fertiliser inputs, no fungicide or insecticide using all broad leaf species allowed for chemical grass control, which was done before planting and during crop cycle, hail storm at the end of July affected yield this photo taken a month after the hail storm, 174 bushel per acre yield.

Resulting yield was only enough to cover costs, but they measured a almost doubling of soil carbon where the extra species were as where they weren't and a substantial rise in biological diversity and numbers without reducing yield compared to the conventionally treated field next to it.

So you saw my first attempt at plant diversity in earlier slides, this was my next attempt in 2015, a duel crop of sugar cane and sunflowers planted within a week of each other in early May.

Increase sunlight capture, increase biological diversity, increase air and water infiltration, increase organic matter.

The same crop being harvested in October,.

Also increased competition for the cane, weed control difficult, although where sunflowers thick enough weeds were just as suppressed as the cane.

Within this area we did hand weed several small plots to try and get an idea of the competition effect and the loss of cane yield, those plots suggested we would have yielded 130tph without the sunnies, the 1.7 tonne of sunflower produced compensated for the 18tph loss in cane production. This block remains in the top 10% production wise on my farm, although I think it will need to be intercropped to maintain the biological diversity that I had created.

My latest effort to improve soil health and until now the missing link in my system. 15 different plant species planted into an early cut fallow.

Corn, oats, sorghum, sunflower, safflower, cowpea, lablab, Desmodium, Desmanthus, Lucerne, mung bean, forage rape, plantain, mustard, chicory

Planting completed on the 17/8 cattle grazing by the 4/11 and that was at least two weeks late, we had an extended dry period from mid May to mid October and since then over 200mm.
High intensity short term grazing, 25hectares split into 10 cells. Shifting the cattle every four to seven days depending on numbers and plant growth in each cell.

The idea is to eat one third, trample one third and leave one third standing for regeneration.

For my last slide i would like to leave you with the idea of just how global Nuffield is, this photo is of the 2014 Nuffield scholars from across the world and the guest presenters that we listened to at the contemporary scholars conference in Sydney back in March 2014.

It is a very diverse group of 93 people from 15 different countries from every continent on the globe and from most forms of agriculture.
Nuffield has been supporting scholars for the last 64 years and has built up a very extensive network of contacts in all aspects of agriculture across the world, we need access to those contacts to encourage learning in our industry.

Nuffield Australia awards between 18 and 24 new scholars every year, we need at least one of them to be from the sugar industry every year.

If you want to know more just Google, Nuffield Australia. There are reports on their web page from all facets of agriculture that are available to all.

THE POWER OF KNOWLEDGE IS THE POWER OF NUFFIELD.

Thank you.