Slide 1

Soil Masterclass

Nicole Masters

www.integritysoils.co.nz

Slide 2

Agroecology

- **Agroecology** is the study of ecological processes in agricultural production.
- Results in novel management approaches.
- Work in a variety of agroecosystems,
- Not associated with any one particular method of farming.

Slide 3

Agroecologists do not oppose technology or inputs; instead assess how, when, and if technology can be used with natural, social and human assets.

There are no 'silver bullets'

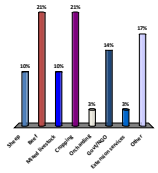
Focus on these 4 pillars;

productivity, stability,sustainability & equitability

Slide 4

What's your business?

A. Sheep
B. Beef
C. Mixed livestock
D. Cropping
E. Orcharding
F. Govt/NGO
G. Extension services
H. Other



Slide 5

Regenerative farming systems involve a complex learning system:

Not an 'add on' but a whole systems approach

Applied in local contexts

Farmers are the 'experts'

(Rolinq, 2007)

Slide 6

Healthy Soils

- Hold onto and release nutrients
- Hold onto and release water
- Have great structure
- Are full of life
- Protect against pests & disease

Slide 7

Healthy soils contd…

- Decompose and detoxify
- Buffer to changeable climate
- Are full of secondary metabolites, plant growth hormones and enzymes
- Grow productive, healthy, nutrient dense crops

Slide 8

Which all means...

Resilience
Productivity
Animal health
Reduced need for inputs
Reduced costs $$

= PROFIT!

Kenny, G. (2011). Adaptation in agriculture: lessons for resilience from eastern regions of New Zealand. Climatic Change, 106(3), 441-462.

Slide 9

Foundations for success

There are no silver bullets here

OBSERVATION, INTERPRETATION AND ACTION

Where is your soil program at right now?

Slide 10

Without measurement, there is no management

How do you know which way your program is going?

Huge instability with soil/plant tests when microbiology/humus is low

Slide 11

Site selection

- Compare same site over time
- Same time of year/moisture
- Make sites easy to replicate
- Take photos
- Site-to-site comparisons (same soil type)
  - Different management/treatments
  - Problem areas

Slide 12

Integrity Soils rec

- Choose smaller areas to replicate
- Take mineral (15cm), microbial and plant tissue tests for baselines
- Optional; subsoil tests (15-30cm)
- See attached field guide for other baseline measures

Slide 13

How can we assess health?

Soil indicators	Plant indicators
Soil structure/ porosity	Brix/EC/pH
Colour and # of mottles	Plant growth
Soil Colour/carbon	Legume nodules
Earthworms/dung beetles	/pests/disease
Soil smell/taste?	Plant colour and urine patches
Infiltration rates	Pasture utilisation
Surface relief	Root length and density
Temperature	Area of bare ground
Penetrometer, pH, EC	Drought stress
Soil mineral/biological testing	Input costs to maintain
Enzyme activity	Plant tissue tests
Extractable minerals	

Slide 14

How do we get our nutrients?

- Biology provide enzymes and acids to help make foods smaller and pass these through with vitamins and other metabolites into our bloodstream.
- WE HAVE BLOWN OUR MICROBIAL BRIDGE; with numerous consequences for health; crohns, MS, diabetes, autoimmune, etc etc

Slide 15

The key players…

- Bacteria
- Archaea
- Fungi
- Flagellates
- Amoebae
- Ciliates
- Nematodes
- Algae

} Collectively called Protozoa

Slide 16

Bacteria and archaea

- Oldest, simplest, most numerous organisms
- Involved in:

disease suppression, nutrient retention, N cycle, decomposers

- Make fine Microaggregates
- Consume simple sugars; green materials, sugars

Slide 17

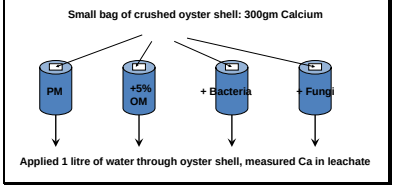
Fungi

- Disease suppression
- Retain nutrients (calcium as calcium oxalate)
- Form soil macroaggregates
- Decomposers – complex foods; lignin, cellulose …

Slide 18

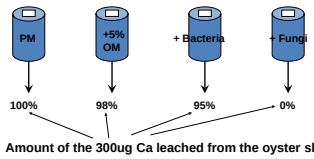
Sandy loam soil, no OM, sterile, re-packed to same bulk density

Bag with oyster shell on surface of each replicate of the following treatments



Slide 19

Sandy loam soil, no OM, sterile, re-packed to same bulk density



Amount of the 300ug Ca leached from the oyster shell

Slide 20

Why calcium?

- Balance minerals in the soil/plant
  - Resistance to many weeds
- Lift pH
- Reduces salinity
- Improves water movement
- Cell wall strength
  - Resistance to pests and disease

= PROFIT!

Slide 21

Fungi and Soil Structure

- Fungal hyphae (threads) help hold soil granules together
- Fungal exudates (goo) help cement soil particles together

Active Fungi Present -
Soil structure is maintained
= Aggregation

Fungi absent -
Soil structure is not maintained
=Sludge

Slide 22

Erosion and WATER holding

- Soil microbes and humus help to build soil structure, water holding & increase resilience to erosion

Slide 23

Protozoa

- Smallest single-celled animals
- 3 main groups
- Ciliates
- Amoeba
- Flagellates

Slide 24

Protozoa

- Food source for higher organisms
- Soil Structure
- Eat 10,000 bacteria in a day

Vital - nutrient cycling = PROFIT

Slide 25

Protozoa Tea

- Soak GOOD lucerne hay or sweet meadow hay in water for 3 days
- Apply between 5-50 litres/ha – trial!
- Release 60% of N and P held by bacteria

Slide 26

Nematodes

- Non-segmented worms
- 95% are beneficial
- "Root body guards"

Could be 1000 nematodes in a teaspoon of low fertility soils

Up to 1,000,000 in healthy soils!

Slide 27

Nematodes contd

- Vital in nutrient mobilisation
- Feed on the primary decomposers (bacteria, fungi, actinomycetes) plus algae and each other
- Central in maintaining F:B ratios – can eat 5,000 bacteria in an hour!

Slide 28

Nematodes are awesome

- Release nutrients (N, S, P) contained in microbes bodies
- Vulnerable to disturbance;
  - Salt fert, soil structure loss
- Quality compost and vermicast are good sources

Slide 29

95% from air/water

Slide 30

Carbon

- Element of Life
- Bio-active forms are key
- Carbohydrates; CHO
- Organic Acids
- Humus
  - Water holding capacity
  - CEC
  - Bio-food sources
  - Soil structure/aeration

Slide 31

Carbon – for stability

- Soil carbon is the foundation for soil health
- Linked to N cycle
- Buffers soil temperature
- Food for microbes

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Slide 32

N & C

- Nitrogen and carbon are intimately linked.
- Protozoa grazing lifted plant N by 75%
- Systems high in bacteria, without protozoa = immobilisation of N

Slide 33

Solar Farmers

- Our success as farmers is governed by how well we support plants in capturing sunlight energy; converting it to sugars

Slide 34

Refractometers

- The function of plants is to produce sugar which lead to the manufacture everything which goes out the farm gate!

  = PROFIT

- Refractometers are a simple tool which help to quantify how well photosynthesis is working.

(see attached information on the use of refractometers)

Slide 35

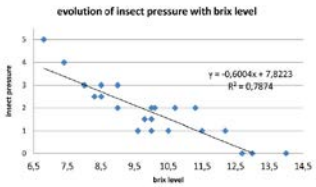
Brix

- A measure of sugars & dissolved solids
- Optimal photosynthesis and plant health occurs when the brix is 12 and over
  - with unrolled sample

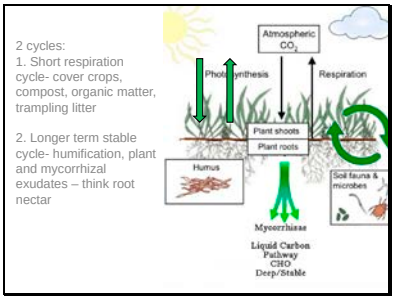
Slide 36

Pests, weeds and diseases are influenced, either directly or indirectly, by nutrition and brix

Slide 37



Slide 38



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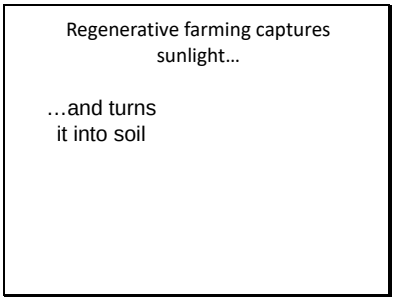


Slide 40

Two neighbouring orchards

Integrated system

No compost application, herbicided rows, irrigation,

→ 2.6 kg C/m² (top 0.1 m)

Biological system

Compost application, pasture in rows, no irrigation,

→ 3.8 kg C/m² (top 0.1 m)

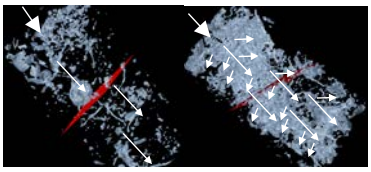
Soil carbon management: A recipe for a healthy macro-porous soil structure

M Deurer, B E Clothier, K Müller, 2006

Plant & Food RESEARCH

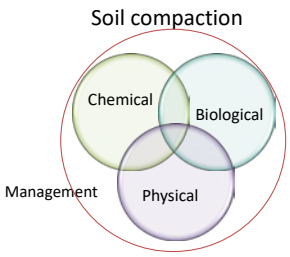
Slide 41

Macro-pores enhance the mixing of nutrients and contaminants



= better buffering of nutrients and filtering of contaminants

Slide 42



Slide 43

Two camps

- "All you need is biology"?
  - Sometimes…eventually…with optimal management?
- "All you need is X, Y, Z?"

Slide 44

Reams Testing (La monte)

- Indicative of plant available element
- Mild extraction process
- Gives a more thorough indication of soil health and biological activity
- Functional ratios important

Reams test offered by Environmental Ag Labs, Southern Cross University

Slide 45

Reams test

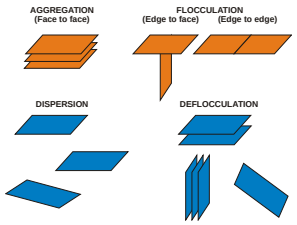
- Ca:Mg ratio -maintain soil structure and encourage soil microbes
- Functional Ca:Mg 5 - 7:1

Slide 46

Ca:Mg ratio

- When Mg is high, soils tighten which;
  - impacts on micro-organisms
  - reduces the N, C and water cycles
  - reduces availability of other nutrients

Slide 47



Slide 48

What can we do for compaction ?

Slow and steady

- liquid limes (see recipe attached for whitewash)
- Cover crops; chicory, brassicas, tillage radish, sunflower…diversity!
- Feed biology

- How much time?…

Slide 49

For faster results

- Add calcium (with C) to lift Ca:Mg ratio
- Add gypsum to drop high Mg
- Rip and drip with bio foods and liquid limes

Slide 50

Too much of a good thing?

- Avoid overdoing…anything!
- High Ca to Mg– light soils, prone to drying up quickly, leaching increases
- High Ca soils can lock up or release other nutrients in excess

Slide 51

‘Perfect’ soil test numbers?

- You can still have soil and plant nutritional issues.
- No numbers are perfect, unless all numbers are perfect
- What is functional?
- Management will trump numbers

Slide 52

Ian & Di Haggarty

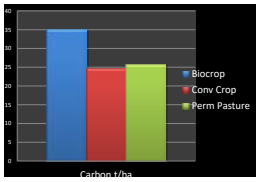
Prospect Pastoral Co, Wyalkatchem
Sheep and cropping
8 inches average annual rainfall

Post grazing- seed drilled with biological brew: 5 litres vermi-liquid, 10 litres compost extracts and 4 units N

Year round groundcover as much as possible

Slide 53

Carbon stocks (top 30cm)



Slide 54

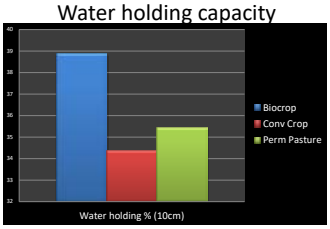
Carbon sequestration

There was a **41.46%** increase in soil carbon stocks (t/ha) (top 30cm) = **10.26 t/ha extra C**

Australian National Soil Carbon Research Program (SCaRP) data

Slide 55

Water holding capacity



Slide 56

Haggerty's soil test results

% increase compared to neighbour

Soil carbon	41.5%
Soil nitrogen	27.7%
SWHC	13%

(SWHC = soil water holding capacity, CSIRO data)

Slide 57

Carbon and nutrients

↑ Increased C =

↓ - decreased pH, CEC

↑ - availability of P, Ca, K, S, Cu, Zn, Fe, Mo, B

availability of Na, Al

Slide 58

The improvement in soil carbon was more pronounced at depth …..

Increment	% increase
0-10cm	36.9%
10-20cm	40.5%
20-30cm	53.6%

Slide 59

Haggerty's have ….

i) Increased photosynthetic capacity
ii) Increased soil biological activity

Brix levels in wheat up to 25
Brix in conventionally grown wheat commonly 2 or 3

Slide 60

OUTCOMES

- Less use of acidifying/high salt index fertilizers -reduces need for liming
- Improved **Soil Tilth** = Decreased Fuel Usage.
- Improved **Water Holding**
  - Improved Resilience & Recovery during prolonged dry spells.
- Improved Grain-Fill, Hectolitre Weight, Decreased Screenings/sprouting.
- Nil crop residues at harvest

Slide 61

Soil Carbon and Water

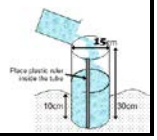
How much water does 1% C hold in an acre?
(to 12 inches depth)

15,600 gallons per acre
Est 30% loss C =
866,000 gallons/acre???

Slide 62

Infiltration test

- Cut a piece of downpipe 250mm long.
- Bevel the edge
- Bang in with a mallet 100mm deep
- Pour in 25mm water. Time.
- Pour in a 2nd 25mm. Time.



Slide 63

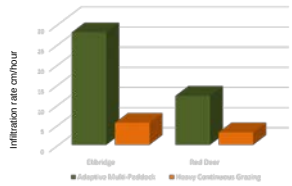
Infiltration test

- If the water takes longer than 2mm/min to absorb, your soil is in trouble!

= soil loss, water loss, loss in production

Slide 64

Infiltration rate changes with changes in grazing management



Slide 65

5 tools to kickstart water cycle

- Feed underground workforce
- Maintain greencover
- Optimise grazing
- Buffer any chemicals
- Diversity, diversity, diversity

Slide 66

Non-wetting soils

- wax isolates are consumed by *Serratia marcescens, Pseudomonas aeruginosa, lots of actinomycete spp* and *Bacillus subtilis.*

Slide 67

Frost resistance

- Relationship with free N, brix and microbiology
- Pseudomonas fluorenscens
  - Naturally in healthy env
  - Down to -5 protection
  - 2 months after application

Slide 68

pH is a symptom

- Hydrogen
- Mineral balances
- Microbial balances
- Moisture

Slide 69

pH and rhizosphere

- Plants with a healthy root biosphere can modify the pH e.g from 5.5 to 6.8 pH
- N-fixing bacteria require a pH of 5.8-7

Slide 70

Cation Exchange Capacity CEC

CEC = number of negatively charged sites on a colloid that are able to hold cations

Colloid – soil particle surface

Cations - have a positive charge

Ca^{2+}, $Mg2^{+}$, K^{+}, Na^{+}, H^{+}, Al^{3+}

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Slide 71

Cations (+ve charge)

- **Bases** are cations which are alkaline and raise the pH

  eg; Ca^{2+}, $Mg2^{+}$, K^{+}, Na^{+},
- **Acid cations** are the cations which increase soil acidity and lower pH

  eg; H^{+}, Al^{3+}

Slide 72

CEC

- Sandy soils have a smaller surface area and carry less negative charge, therefore they have a lower CEC. Therefore have less binding sites for cations and water.
- Mineral imbalances can be corrected quicker
- % Carbon can be increased faster

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Slide 73

CEC

- Clay soils or soils with high humus or OM have a much larger surface area and carry more negative charge, therefore they have a higher CEC. Creating more binding sites for cations and water.
- Mineral imbalances can take a lot of time and money to correct.

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Slide 74

Base Saturation

- Albrecht carried out years of study (1918 - 1974) on plant and animal health relating to Base Saturation.
- Animals preferred to graze, were healthier and produced healthier generations, where the CEC was filled with the following bases;

Ca = 60-75%, Mg= 10-15%, 2-5% K, 1.5% Na

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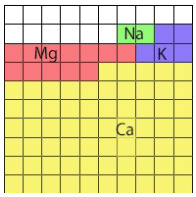
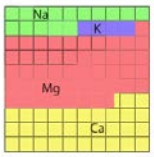
Ideal Base



Slide 76

Case study



- Ca = 32.4%
- Mg= 48.6%
- K = 4.0%
- Na= 15.0%

Slide 77

Calcium- the mother

- Disease and parasite resistance
- Cell division/elongation
- Cell wall binder – pectates/gene orientation
- Nature's detoxifier
  - Key for heavy metals

Slide 78

Ca deficiency

- **Symptoms:** blossom-end rot, bitter-pit in apples, death of root tips, die-back of terminal buds, premature shedding of flowers and buds. Fruit storage.
- **Nature's detoxifier:** **Key for heavy metals**
- **Growth Energy -** slows any seesaw action between growth and fruiting energies

Slide 79

Calcium

- Moves down the soil profile
- Needs boron and moisture to move through the plant
- Is held in soil by fungi
- ALWAYS apply calcium with a carbon source

Slide 80

Phosphorus – the father

- A shortage of phosphorus means a breakdown of the **transmission of energy in plants** and as such prevents growth.
- **Fruiting Energy**
- Phosphorus is part of nucleic acids and phospholipids (the basic molecule of cell membranes). Phosphate essential in energy transduction (ATD, ATP)

Slide 81

Phosphorus

- Deficiency
  - Phytocyanins produced in plant to protect from UV= purple colour

Slide 82

The WA 'P' problem

- WA has low natural phosphate levels
- Highest natural flora adapted to low P
- Only 6% of native spp in low fertility areas are mycorrhizal
- Non-AM –protea, lupins, sedges and rushes

Slide 83

What does it mean if plants are non-mycorrhizal?

A. They don't form glomalin

Slide 84

Glomalin

- A complex glue
- Stable carbon
- Forms soil aggregates
- Gives soil its lovely sticky dark brown colour

Slide 85

Do you have all the phosphate you need?

- P is a catalyst; recycled in the plant for energy
- 90% of available P is bound in plant roots and organic matter
- Soluble P fertilizers are highly inefficient

Slide 86

Phosphate

- Cover crops; faba bean, white lupins and oats use carboxylic acids and protons to release P
- Use small amounts at seeding – buffer with C
- Increase P efficiencies
  - fish, manure, adding carbon, P-solubilising bacteria, VAM
  - Use slow release P forms; e.g. guano, rock phosphate (in acid soils)

Slide 87

Get more P for your buck!

Release bound P with:

- Some Plant Growth Promoting Bacteria(PGPB) solubilize phosphate
- Several enzymes
- Mycorrhizae
- Organic acids

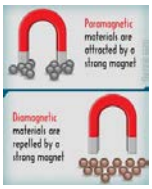
Slide 88

Day 2

- The problem with Australia….
- Oldest soils on earth
- Leached out, high Al, high Na in places
- Low paramagnetism

Slide 89

Paramagnetism



- Paramagnetic (soil)
  - Oxygen, carbon, silica, volcanic rocks
- Diamagnetic (plants)
  - Copper, zinc, diamonds

Slide 90

Paramagnetic soil benefits

- water retention
- increase microbial action
- better nutrient utilization
- improved germination
- Pest resistance
- Buffer to env stress

Slide 91

Paramagnetism

- Measured as gauss/million or cm/gm/sec
- 0-100 = not good soil
- 100-300= good soil
- 300-700 = very good soil
- 700-1,200 = excellent soil

(good volcanic rocks - 1000 to 2,000 μCGS)

- Most Aussie soils are less than 100.

Slide 92

Ways to increase paramagnetism

- Balance calcium to magnesium ratios
- Increase organic matter
- Stimulate biological activities
- Add paramagnetic rock dusts

Slide 93

The further a system moves from nature the more stress it experiences

- C, N, P and water cycles working
- Locally adapted flora
- Plant specific biology
- Nutrients as/when required

Slide 94

How do plants grow in nature?

- No bare ground
- Interconnected
- Collaborative and competitive
- Edge effects
- Diversity – above and below ground
- Grasslands- 80% carbon underground
- Forests- 80% carbon aboveground (90% of carbon in soil held in fungi)

Slide 95

Diversity is key

Fostering diversity provides multitude of benefits… secondary metabolites, health properties, beneficial insects/ animals, weed competition, mycorrhizal guilds, access to water, soil microbes, nutrient exchange, humus…etc etc etc

Slide 96

Cover crops

- grown between cash crop cycles or
- intercrop with cash crops,
- or plant in the absence of a normal crop.

Slide 97

Cover crop benefits

- Soil health; structure, release nutrients, carbon, feed microbes, break up hardpans, improve water cycle,
- Protect soil surface
- Diversity for beneficial insects
- Mycorrhizal refuge
- Build resilience

Slide 98

Modern Ag focus

- Yield, fertilizer use efficiency and disease resistance.
- Do not typically consider interactions with resilience, soil microflora or carbon.

Slide 99

Root and carbon inputs/year

- Spring wheat had 2000 to 2900 kg/ha
- Grassland soils ranged from 18,500 to 36,600 kg/ha
- Wheat had less than 10% of the belowground plant matter

McGill, W.B., J.F. Dormaar and E. Reinl-Dwyer 1988. New perspectives on soil organic matter quality, quantity and dynamics on the Canadian Prairies. In Land degradation and conservation tillage. Proc. 34th Annual Meeting of the CSSS, Univ. of Calgary, Calgary AB, pp 30-48.

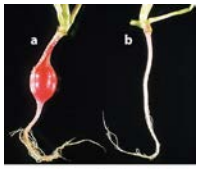
Slide 100

Root development

- Encourage rapid dense root development
  - Roots need P
  - Plant growth hormones; auxin and ethylene
  - PGPR (plant-growth-promoting rhizobacteria)
- Reduce limitations; pH, aluminium, sodicity

Slide 101

Plant growth promotion by a bacteria.



Roots of 17-day-old radish plants.
Seeds inoculated with (*a*) auxin-producing *Pseudomonas corrugata* (*b*) without added microbes.

Lugtenberg B, Kamilova F. 2009. Annu. Rev. Microbiol. 63:541–56

Slide 102

Rhizosheath

- Protection through polysaccharides, glues, mucus, fungi and bacteria
- Buffers against pH, Al, Na

Slide 103

Seed treatments

- Macro and micro elements, seaweed
- Organic carbons; lignin polymers, humics, starch, worm teas, amino acids…
- Biologicals; PGPB, PSB, VAM, Trichoderma, Bacillus, Pseudomonas, Azotobacter…

Slide 104

Livestock and soil

- Grasslands have evolved to be grazed
- With 'good grazing' soils respond positively to livestock disturbance, manure, urine and microbial populations
- Many food production areas are missing the vital component provided by livestock

Slide 105

Grazing and Roots

Grasses have evolved to flourish under periodic grazing pressures

Amount of plant grazed	Time for root recovery	Root growth on 33rd day
90%	No root growth for 17 days	60%
60%	55% after 5 days	192%
30%	117% on 3rd day	250%

Slide 106

Livestock and biology

- Probiotics and healthy gut systems
- Use livestock to spread microbes and seeds
- Holistic grazing principles- spread manure and urine, trample pastures

Slide 107

What is the purpose of agriculture?

- FOOD PRODUCTION

Slide 108

- Many agricultural scientists deny that there is any link between human health and what happens on-farm, however…

  Minerals in food are declining:

  30 to 60% decline in mineral values since 1940 across the developed world: Se, Zn, Mn, Mg, Ca, and vitamins (WHO data)

Slide 109

Where has all the nutrition gone?

- Comparison of 19,000 feed samples, 298 biological farms had:
  - 6% ↑ Crude Protein
  - 47% ↑ Calcium
  - 16% ↑ Phosphorus
  - 11% ↑ Potassium
  - 29% ↑ Sulphur

• US Data, Dairyland Laboratories

Slide 110

Nutrients

- 16 nutrients for healthy plants
- 60 nutrients for healthy animals and humans
- How many of these nutrients are rotuniely applied in conventional fert applications?

Slide 111

Biological inputs

- Include broad spectrum nutrition in seaweed, fish products, compost extracts,
  - they also contain foods, vitamins, enzymes and hormones for plant and biology growth

Slide 112

Case Study: Big Timber Alfalfa Program

- 10 litres fish hydrolysate
- Manganese sulphate
- Borate
- 2 kg sea mineral

Slide 113

Results: Plant tissue testing

	Conv	Bio	Supreme
Protein	21.9	29.5	>22
NDF	37.5	28.5	<34
TDN	62.4	70	>62
RFV	155	222	>185
Ca	1.99	1.77	1.71%
P	0.29	0.4	0.38
K	1.21	1.84	2.4
Mg	0.42	0.49	0.34

Slide 114

Case Study: Sheep and Beef NZ

Shortlands Station, 6,500 ha South Island high country
300-400mm average rainfall

Slide 115

CASHFLOW

QUALITY CARCASES

QUALITY PRODUCE

In a cutting study of over 10,000 lambs, 13% increase in meat/bone over all other lambs.

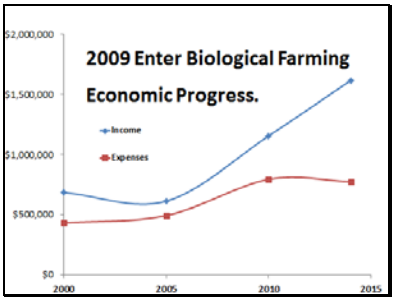
Slide 116

Table 2. Shortlands Station economic and management parameters benchmarked to Beef & Lamb South Island Hi County sector average ($/Stock Unit).

Year		2012/13		2013/14	
Class	Shortlands	S.I Hill	Shortlands	S.I Hill
Gross farm income	99.96	81.04	105.31	85.08
Animal Health	2.95	5.08	2.98	5.18
Lime & Fertiliser	8.23	7.15	11.97	7.68
E.B.I.T*	41.24	25.36	50.68	27.69

** Earnings before interest and tax

Slide 117



Slide 118

Shortlands Programme

- Apply 15 litres of Fish to all younger paddocks.
- Balanced Ca/Mg ratio: 7-1
- 20 kg D A P with 2kg Humate
- All seeds sown with a microbial innoculant:
  - mycorrhizal fungi, pseudomonas, baccillus bacteria

Slide 119

If we don't foster our underground workforce, then the services they provide are paid for by the wider environment, and own our back pockets.

Slide 120

Taking action

Start with reducing practices/inputs that are harmful…

E.g; pesticides, herbicides, excess manure, high soluble fertiliser, too much tillage or tillage when wet,

Then buffer remaining inputs with a carbon source

Slide 121

Taking action

Positive actions for soil health:

E.g. create an armour on soil surface, diversity (above and below ground), biological stimulants, seed treatments, bio-control agents, compost extracts, treated manure, carbon inputs, shallow incorporation of crops, pasture cropping, integrated designs- keyline, permaculture, natural sequence farming …

Slide 122

Next step

- Keep up with education; read, call people, watch online clips; Gabe Brown, Dr Christine Jones, BioIntegrity Wheat, Dr Elaine Ingham, Peter Byck, Ray Archuleta, Gary Zimmer, Colin Seis, www.WIG.farm

Huge thanks to SRF, Nick Kelly and Warren Pensini for supporting this event, and to you!

Slide 123

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