NORTH CENTRAL
Catchment Management Authority

SOIL HEALTH PANEL DISCUSSION NCCMA HUNTLY

WORKSHOP OUTCOMES REPORT

24 JULY 2007

PREPARED FOR THE NORTH CENTRAL CMA BY:
THE REGIONAL DEVELOPMENT COMPANY
As part of a NAP Funded project.

Australian Government

Contents

Introduction

A full day Regional Soil Health Expert Panel Discussion was conducted on Tuesday the 24th of July 2007 in Bendigo. Daniel Mudford, team leader – land North Central CMA opened the forum and reminded participants that the forum was a follow up forum from a larger event last year. The soil health event held last year attracted many participants highlighting the interest in soil health in the catchment. Feedback from that event suggested the need for a follow up forum for a smaller group that gave greater opportunity for participation.

The objectives of the Regional soil Health forum were:

- To clarify the key soil health issues for Land Mangers in the North Central catchment area
- To identify key strategies to address these soil health issues in the catchment
- To develop options for supporting land managers to implement these strategies

Amanda McClaren, Regional NLP coordinator for the North Central CMA, outlined the key soil health issues nominated by landholder participants prior to the forum. These included:

- Soil Biota and the effect on soil health
- Soil carbon and the effect on soil moisture retention and CEC
- Soil acidity and the effect on production
- Overall management of soil fertility
- Soil structure and the relationships to crusting and compaction issues
- *Salinity

*Whilst Salinity was mentioned by a number of the Land Managers as a significant soil health issue in the North Central region it was decided that the Dryland Management Plan already has a large Salinity focus. Therefore for the purposes of this exercise salinity was acknowledged as an issue but was not included in the key soil health issues to be addressed on the day.

A Panel of experts were invited to respond to each soil health issue. Panel members included:

- Dr Pauline Mele (DPI)
- Dr Maarten Stapper (Ex CSIRO)
- Richard Macewan (DPI)
- Gwyn Jones (Independent Agronomist, Integrated Agriculture)
- Keith Reynard (DPI)

Participants were invited to discuss their current practices to address soil health issues on their properties and to discuss potential options they have been contemplating. The whole group then identified the key issues worth exploring further in the catchment and potential next steps for the North Central CMA to develop a soil health program for the catchment.

This report documents participant responses to the facilitated session.

Soil Health Issues

Soil Health Issue	Key Considerations	Potential Strategies
Soil Biota and the effect on soil health	• Soil Biota are important for nutrient cycling in soils and can be a source and a sink for plant nutrients • Soil Biota can decompose chemicals • Very important for improving soil structure • Soil biota can promote plant root growth and reduce disease causing organisms • Needs further research – still a lot we don't know	• Engage with researchers to encourage research sites in the North Central catchment • There are many soil biota tests available, however there is a need to identify the appropriate test most suitable to your requirements and the knowledge you are seeking
Soil carbon and the effect on soil moisture retention and Cation Exchange Capacity (CEC)	• There is much potential for carbon to be stored in soils and is very important for overall soil health • Carbon levels are very low in agricultural soils especially cropped soils • There are different components of soil carbon that have different roles • Particulate organic matter is the key food source for soil biota • Humus has a very high CEC and will increase soil fertility • Soil carbon enables greater levels of soil moisture to be stored	• Stubble retention and reduced stubble burning • Pasture phase in crop rotation will increase organic carbon • Careful stock management – cell grazing is important • Need to explore other methods of measuring soil carbon • Aim for 100% cover of the soil by vegetative matter 100% of the time.
Soil acidity and the effect on production	• Acid soils can have a major impact on production by influencing the availability of plant nutrients and toxic elements such as aluminium and manganese • In Victoria, 4–5 million hectares are strongly acidic • Soil acidity is measured by pH and is a measure of the hydrogen activity in soils • Can be measured in the laboratory and in the field	• Lime acid soils to raise the pH of soils and reduce available aluminium • Manage nitrogen on farm to reduce leaching • Soil test and include assessment of aluminium

Soil Health Issues — continued

Soil Health Issue	Key Considerations	Potential Strategies
Overall management of soil fertility	• Need to start with an assessment of soil chemistry, soil physical properties, and soil biology • Can use easy in the field observations to assess soil fertility such as observing the plant species present • To assess soil chemistry need to test the pH, the Ca/Mg, and N,P, K and S balance • Examine soil structure and compaction in the field with a penetrometer and a spade	• Careful selection of limes and gypsums and phosphorus source • Review plant species succession • Assess topsoil depth and work towards growing topsoil
Soil structure and the relationships to crusting and compaction issues	• Soil structure is important for penetration of water, air and roots into the soil • Soil structure can be assessed in the field by observing the size, shape and arrangement of soil aggregates • Crusting can be caused by dispersion and low organic matter in topsoils • Dispersion can be assessed in the field by dropping an aggregate into water and observing what happens • Soil strength is low when soils are wet. Compaction can occur when wet soils are trafficked by stock or machinery	• Gypsum can reduce dispersion issues • Organic matter can improve soil structure • Keep soils covered • Reduce traffic on wet soils and reduce tillage

More information on all soil health issues can be found on the 'resources online' website (http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/vrohome).

Current Practices and Potential Strategies to Improve Soil Health

What are you currently doing to address soil health issues on your property?	What have you been thinking of doing to address these issues?
• Stubble retention • Stubble utilization by stock • Laser grading and deep ripping • Deep rooted perennials • Soil testing • Aeration • Rotational grazing • Reducing cropping • Reducing flood irrigation • Encouraging and using worms and insects • Composting • Using inoculants • Liming • Minimum tillage • Compost teas • IPM • Shelter belts and trees • Controlled traffic • Gypsum • Reactive rock phosphate and rock phosphate mixes • Direct drilling • Stopped using water soluble fertilizers and drenches	• Using manures • Using sprouted grain for animals • Farm plan on how to role out the new strategy on the whole property • Sea mineral foliage sprays • Reducing traditional fertilizers and other inputs • Using diverse pastures • Increasing biodiversity • Natural sequencing • Native perennials • Controlled traffic • Yield and quality mapping • Green manures • Foliar sprays • Composting manures • Cutting for silage to reduce weed seed set • Chop and spread stubbles • Press wheels on direct drill

Issues to be Explored Further in the Catchment

- Soil carbon – options for measuring different pools, strategies to increase soil carbon, strategies to increase rooting depth and topsoil depth.
- Soil biology – learning from other farmers, exploring testing options, mapping the tests, encouraging on-farm research.
- Soils and landscape relationships – how does soil capability change across the landscape, soil structure issues and natural sequence farming in landscapes.
- Soil acidity and alternative soil treatments – explore lime and alternative soil fertilizer treatments in trials.

Preferred Options for Exploring Soil Health in the Catchment

- On farm trials and demonstration sites with field days.
- Look at farmers already doing it – perhaps explore mentoring options.
- Develop a flow chart on how to change over to being biological.
- Seek research funding for mapping, research and testing for soil biology or seek partner to co invest.
- Use a sub-catchment approach – identify the key soil problems, set up demo site, and develop options.
- Use Landcare to run soil health events.
- Bus tour of soil health projects.
- Communication strategy with information compiled/brochures.
- Carbon road show- what is it, how you can increase it, how to trade it etc.

Next Steps

- Find existing groups in the catchment that have an interest in soil health and work with them initially – start with an opportunity to take a look at soils in the field with experts.
- Develop a system to capture what is already going on – stories / case studies with data to back it up.
- Compile an information list and a list for technical support for landholders interested in exploring soil health further.
- Explore funding options and options for developing partnerships to co invest.
- Explore current options for soil biology testing eg University of Queensland and develop some protocols for sampling.
- Explore the experience of other CMAs with Soil health eg North East CMA.

Where to from Here

Soil health is an intrinsic part of the future direction of the (Draft) North Central Dryland Region Management Plan (DRMP*). Currently the DRMP plan focuses on the protection of assets from salinity with only brief reference to soil health decline as a threat to the regions assets. Over the next twelve months (2007/08 financial year) the information collected from the workshop process will be used to develop the DRMP.

North Central CMA is committed to working with the community on many levels to ensure that Soil Health decline is addressed in a way that the community can understand and is willing to adopt and participate in.

Specific projects that target the recommendations in the “next steps” of this report and from other sources will be developed. Some of these recommendations will be able to be completed through existing projects, for others we will need to create and expand new projects. Where there is a clear public benefit traditional state and federal funding sources will be targeted, where there is greater private benefit, private industry and extension will be the focus of projects.

* A copy of the North Central Dryland Region Management Plan (Draft) is available at www.nccma.vic.gov.au or call (03) 5448 7124.

Appendix

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Soil heath issues raised by participants

Soil Health Issue	Issues raised by Participants
Soil Biology	• Loss of spiders, termites and ants • Lack of organic content in local soils (soils have become just dirt, not living/breathing and biota active) • Lack of knowledge and ongoing research into the importance of soil biota and overall on farm biodiversity, to maintain healthy soils. • Lack of knowledge and ongoing research into the effect of chemicals on Australian soil biota and overall biodiversity, farm lands and community, and what alternative methods can be promoted and used. eg Integrated Pest Management • Improving soil biology • Micro-biology biomass/biodiversity • How to build top soil & biology levels • measuring soil biology health
Soil Organic Carbon	• Organic carbon • Organic matter/carbon levels • Low carbon • use of soil and crop and pastures for carbon sinks • measuring soil carbon and consistency between measurements at different sites. • Organic Carbon Content
Soil Acidity	• Acidity • Soil Acidity (2) • Acid Soils • Soil acidity and acidification • The effects of fertilizers on soils •
Soil Fertility	• Loss of organic material in soils. • pasture productivity • Fertility • Calcium deficiency • using Brix meters to measure crop pasture to help determine what soil solutions are required • improving soil organic matter • Soil capability and suitability

Soil Structure	• Loss of Top Soil • Loss of Perennial Plants and ground cover, especially in summer. • Lack of soil protection from extreme weather conditions, eg shelterbelts • Lack of perennial ground cover to hold rain where it falls and retain soil moisture • Veg cover • Sodocity • Compaction(3) • High water tables – even in the dry period, mainly due to Channel Seepage. • Crusting • Erosion (2) • Water retention • the water holding capacity of different soils • Maintenance of soil structure • Hydrologic performance

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5 July 2007

Dear, Discussion participant,

North Central Regional Soil Health Expert Panel Discussion, Tuesday 24th July 2007.

I am writing to invite you to participate as an audience member at our North Central Regional Discussion on Soil Health. Please find attached the Soil Health Panel invitation flyer with the agenda on the reverse side.

This expert panel discussion on soil health in the North Central Region has been organised as a result of the feedback collected at the successful "Getting Grounded" Soil Health forum held in Bendigo in 2006. Many of the participants from the "Getting Grounded" forum requested a smaller more focussed discussion with a limited audience of astute community members. We are bringing in soil health experts from around Australia to be involved with this discussion driven by issues raised by the community.

The aim of the Soil Health Panel is to discuss soil issues within the region and suggest potential solutions and direction. The audience for the discussion panel will include the farmers, land managers and some other key stakeholders from the North Central region.

Prior to the panel discussion I would like you to think about and identify what you see as the top 5 soil health issues for your part of the region. **Please advise Rhonda Leed of these 5 issues when you rsvp to this event by Tuesday 17th July 2007.**

Once identified, the top 5 Soil Health Issues will be sent to the panel of experts. Each expert will be speaking on a different soil health issue and specifically outline strategies we can use to address the issues raised. Following the expert presentations there will be opportunity to discuss the issues and identify ways to move forward with potential soil health projects

Should you have any questions regarding this event please do not hesitate to contact me on 03 5440 1839 or daniel.mudford@nccma.vic.gov.au

Yours sincerely,

Daniel Mudford
Team leader - Land

Invitation

North Central Soil Health
Expert Panel Discussion

Tuesday 24th July 2007
10:00am-4:00pm
North Central CMA Boardroom

Soil Health repeatedly comes to the fore when we talk about Natural Resource management in the region. As a valued land manager in the North Central Region, we would like to invite you to participate in our regional soil health discussion and identify ways to move forward with potential soil health projects.

Please refer to the agenda overleaf.

Strictly Limited numbers, please RSVP by <u>Tuesday 17th July 2007</u>

to Rhonda Leed Ph: 5448 7124

NORTH CENTRAL
Catchment Management Authority

North Central Soil Health Expert Panel Discussion
Tuesday 24 July 2007

Objectives

- To clarify the key soil health issues for land mangers in the North Central catchment area
- To identify key strategies to address these soil health issues in the catchment
- To develop options for working with land managers to implement these strategies

Agenda

10:00am Participants arrive with morning tea available

10:10am Welcome (CMA)
- Background to the soil health expert panel
- Objectives for the panel

10:20am Introductions and expectations

10:35am Overview of the soils of the North Central CMA
- Key soil health issues nominated by landholders
- Discussion questions: are there other issues that should be addressed?

10:50am Panels Response
- Overview of each soil health issue
- Key strategies to address each soil health issue
- Any new potential ideas to be explored on this issue
- 5 x 15 minute presentations plus 5 minute questions

12:30pm Lunch

1:15pm Table discussions with panel members
- What are you currently doing to address soil health issues on your property?
- What have you been thinking of doing to address these issues?

2:00pm Tables report back
- 2 strategies currently being used by land managers
- 2 strategies land managers are thinking about

2:15pm Whole group responses to the strategies discussed

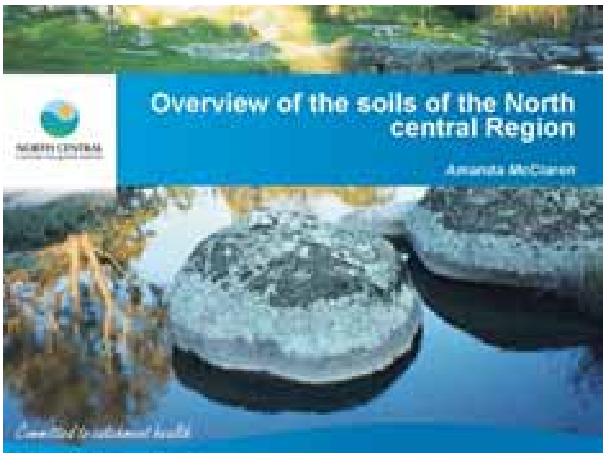
2:30pm What are the options for working with farmers to explore and / or implement these strategies?
Moving table group discussions and recording on butchers paper

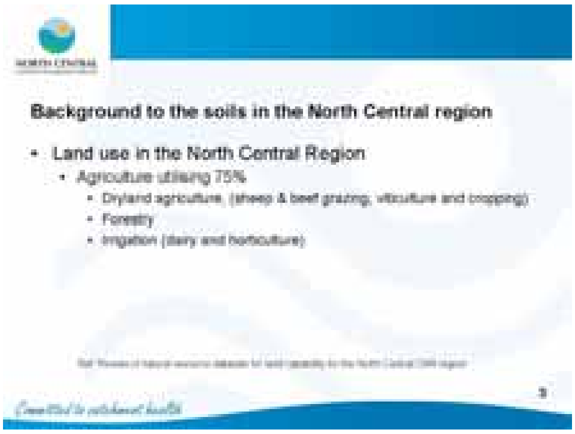
3:15pm Afternoon tea

3:30pm Whole group discussion on the key options, roles and next steps

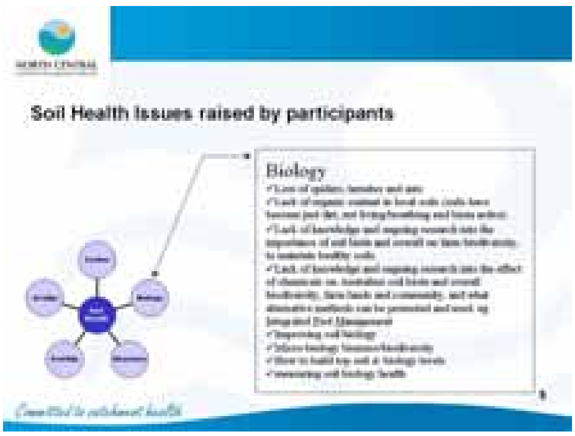
3:50pm Wrap up, next steps and close (CMA)

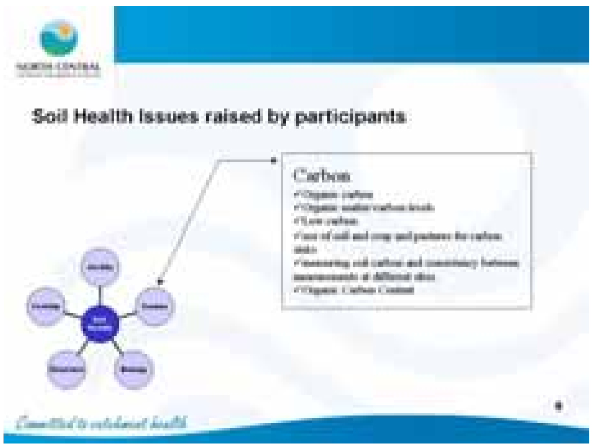

Soil Health Expert Panel Discussion
Tuesday July 24th 2007
Committed to catchment health

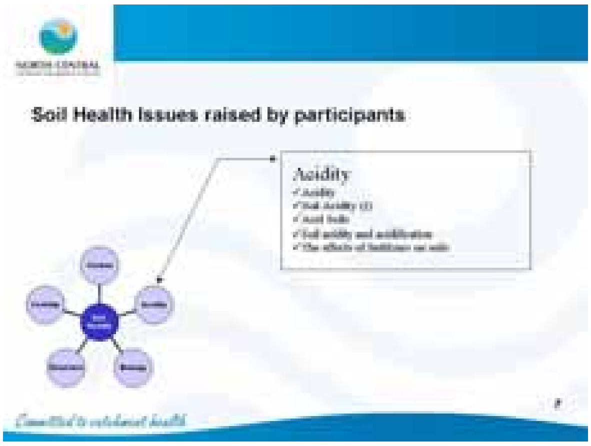

Overview of the soils of the North central Region
Amanda McClaren
Committed to catchment health

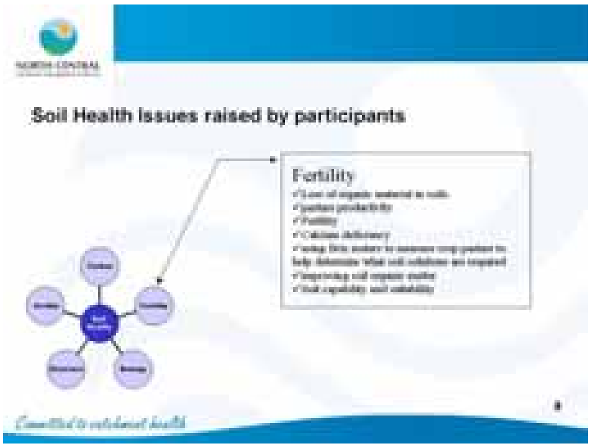

Background to the soils in the North Central region
• Land use in the North Central Region
• Agriculture utilising 75%
• Dryland agriculture, (sheep & beef grazing, viticulture and cropping)
• Forestry
• Irrigation (dairy and horticulture)
Committed to catchment health
3


Key soil health themes
Carbon
Acidity
Salinity
Soil Health
Fertility
Biology
Structure
Committed to catchment health
4


Soil Health Issues raised by participants
Biology
Committed to catchment health


Soil Health Issues raised by participants
Carbon
Committed to catchment health

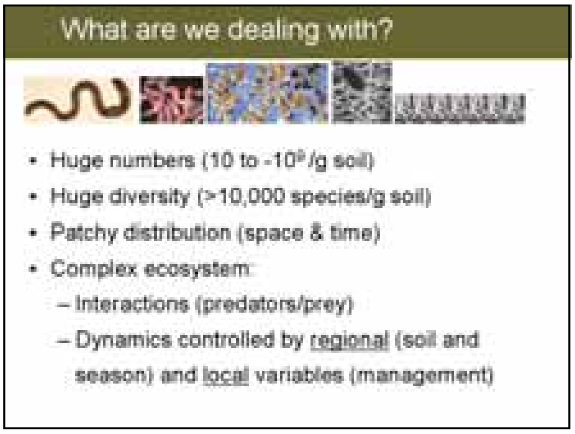

Soil Health Issues raised by participants
Acidity

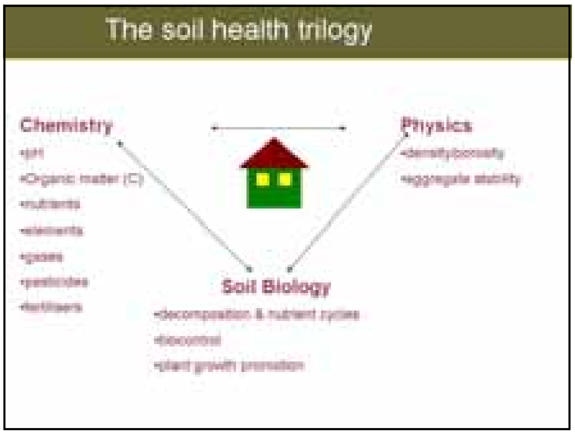

Soil Health Issues raised by participants
Fertility

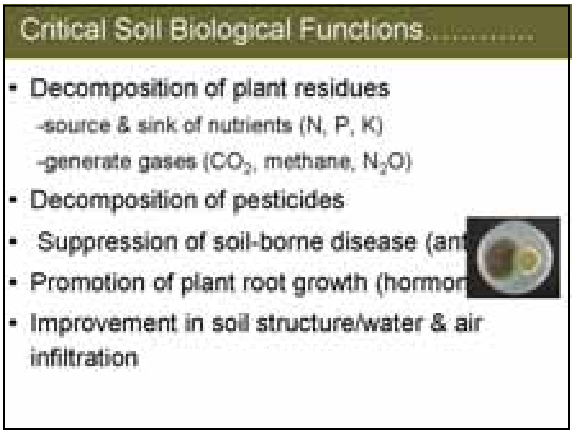

Soil Health Issues raised by participants
Structure

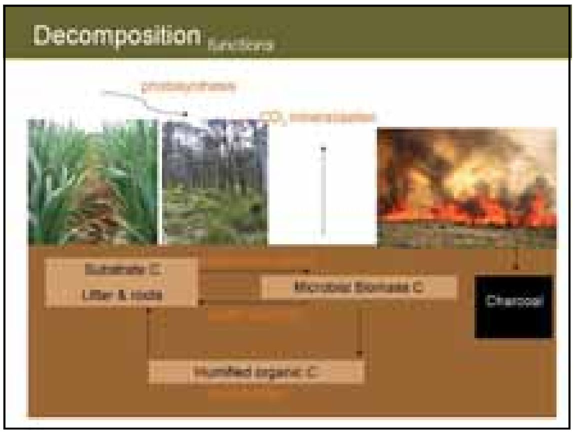

Soil Biota….role in soil health
Overview & Strategies

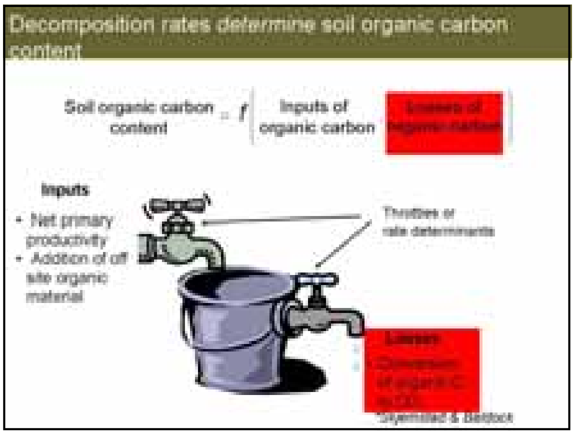

Overview Soil Biota
• What are we dealing with?
• Critical functions
• Measurement
- Methods
- Reference points and value ranges

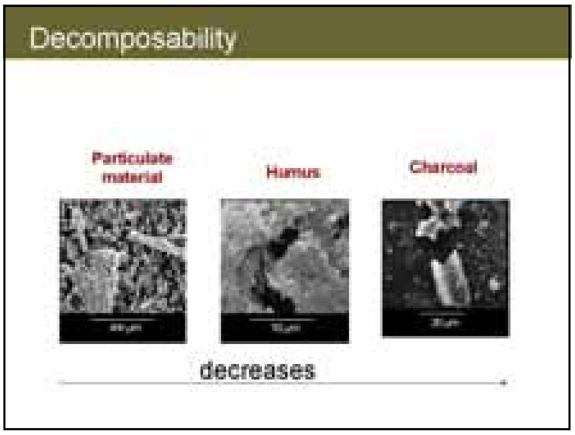

What are we dealing with?
• Huge numbers (10 to -10⁹ /g soil)
• Huge diversity (>10,000 species/g soil)
• Patchy distribution (space & time)
• Complex ecosystem:
– Interactions (predators/prey)
– Dynamics controlled by regional (soil and season) and local variables (management)

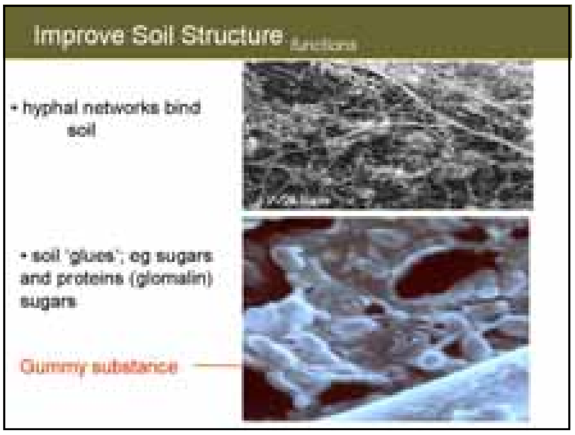

The soil health trilogy
Chemistry
•pH
•Organic matter (C)
•nutrients
•elements
•gases
•pesticides
•fertilisers
Physics
•density/porosity
•aggregate stability
Soil Biology
•decomposition & nutrient cycles
•biocontrol
•plant growth promotion


Critical Soil Biological Functions…………
• Decomposition of plant residues
-source & sink of nutrients (N, P, K)
-generate gases (CO2, methane, N2O)
• Decomposition of pesticides
• Suppression of soil-borne disease (ant
• Promotion of plant root growth (hormon
• Improvement in soil structure/water & air infiltration

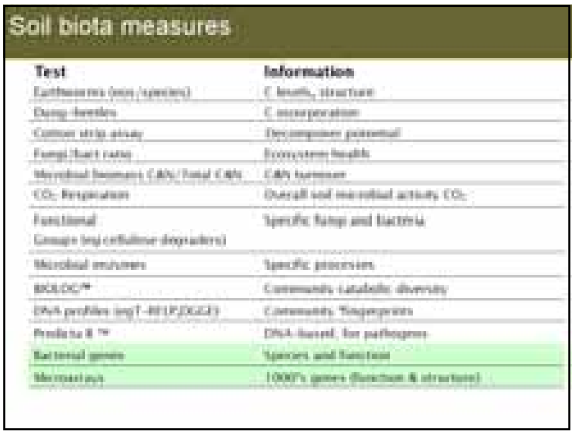

Decomposition functions
photosynthesis
CO2 mineralisation
Substrate C
Litter & roots
Microbial Biomass C
Charcoal
Humified organic C

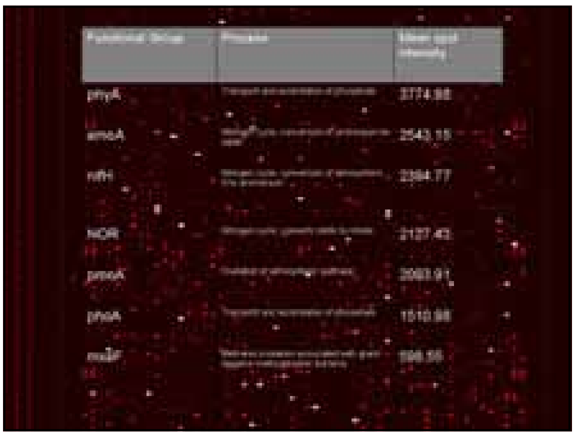

Decomposition rates determine soil organic carbon content
Soil organic carbon content = f
Inputs of organic carbon
Losses of organic carbon
Inputs
• Net primary productivity
• Addition of off site organic material
Throttles or rate determinants
Losses
Conversion of organic C to CO2
Skjemstad & Baldock


Decomposability
Particulate material
Humus
Charcoal
decreases


Improve Soil Structure functions
• hyphal networks bind soil
• soil 'glues'; eg sugars and proteins (glomalin) sugars
Gummy substance


Soil health/resilience measures
1. Dirt kicking exercises (sight, feel & smell)
2. Field-based measures (visual/rapid)
3. Laboratory-based (simple to sophisticated)
4. Must integrate soil physical, chemical and biological properties


Soil biota measures
Test
Information
Earthworms (nos./species)
C levels, structure
Dung-beetles
C incorporation
Cotton strip assay
Decomposer potential
Fungi/bact ratio
Ecosystem health
Microbial biomass C&N/Total C&N
C&N turnover
CO2 Respiration
Overall soil microbial activity CO2
Functional Groups (eg cellulose degraders)
Specific fungi and bacteria
Microbial enzymes
Specific processes
BIOLOG™
Community catabolic diversity
DNA profiles (eg T-RFLP, DGGE)
Community 'fingerprints'
Predicta B ™
DNA-based, for pathogens
Bacterial genes
Species and function
Microarrays
1000's genes (function & structure)


phyA
2774.88
amoA
2543.15
nifH
2384.77
NOR
2127.43
pmoA
2083.91
phoA
1510.88
2
598.55

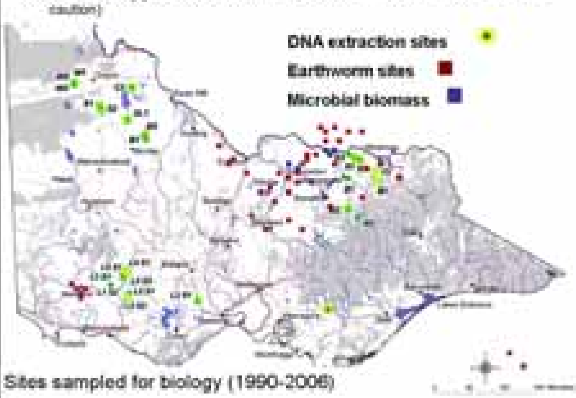
Choose method to fit need

impact	method
tillage	Soil microbial biomass Glomalin production
stubble retention	Specific enzymes involved in stubble decomposition
pesticides	Sensitive species Diversity
fertiliser	N and P cycle bacteria (N-fixation) Diversity
lime	Nitrogen cycling bacteria Diversity

Potential strategies *Soil Biota*

- Integrate and build knowledge

Soil biology data is limited (data must be interpreted with due caution)



Sites sampled for biology (1990-2006)

Potential strategies *Soil Biota*

- Describe major soils of NC Catchment
- Identify priority soil health issues in NC Catchment for each of these soil types
- Achieve consensus on methods based on priority soil health issues and preferred approach (in-field/lab based)
- Build NC soils database (identify and fill gaps in data)
- Establish NC regional targets/reference points and thresholds for effective interpretation

Questions I have

Do you believe that your understanding of soil health is:
Fair, moderate, good, excellent?

If fair to good, what do you feel you need more knowledge of?

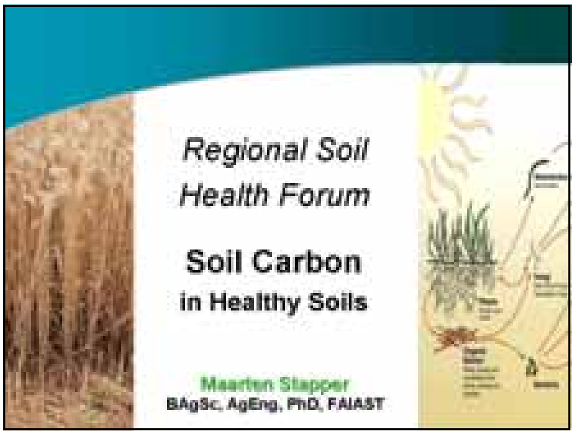
Do you equate soil health with soil biology or are they separate issues?

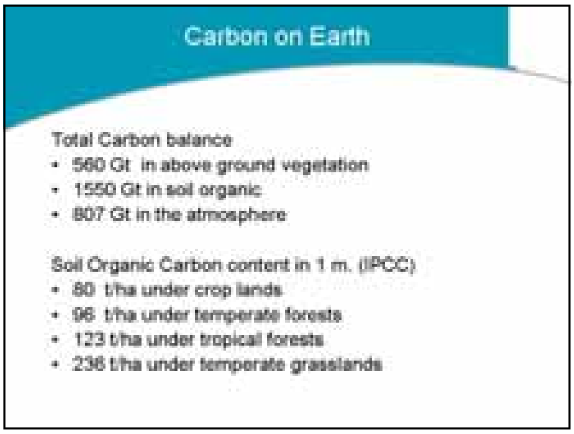
How do you know if you have good soil biological health as opposed to bad?
What indicators/signs would you look for?

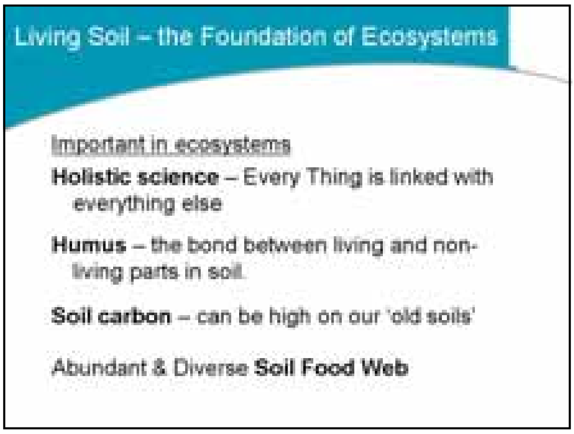
Why are you interested in soil biology?

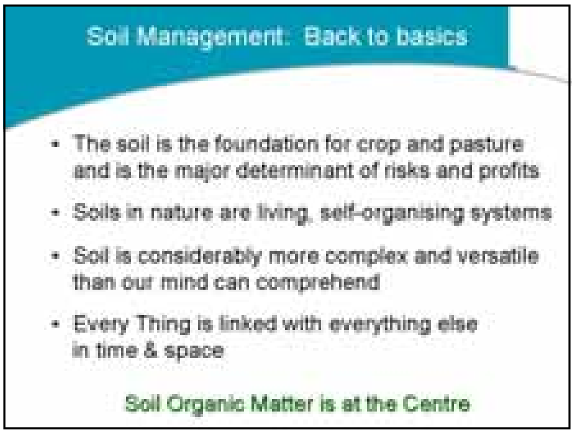
What information would satisfy your needs in soil biology?
Knowledge of what soil biology does but no sustained interest in monitoring
Interest in monitoring with advice on tests available and interpretation

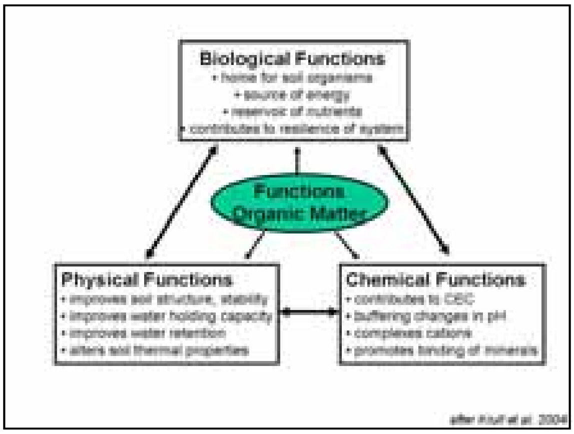
Would you pay for tests and if so what would your expectations be?

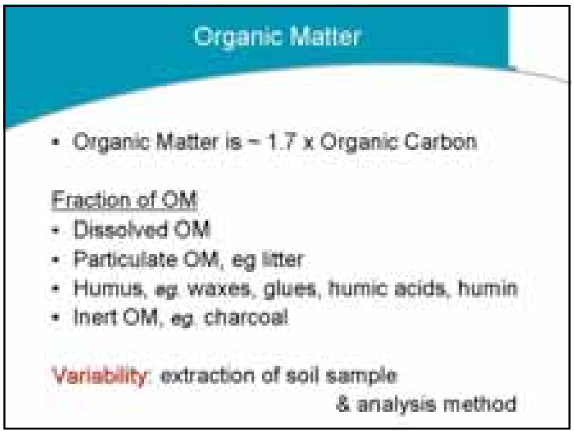

Regional Soil
Health Forum
Soil Carbon
in Healthy Soils
Maarten Stapper
BAgSc, AgEng, PhD, FAIAST


Carbon on Earth
Total Carbon balance
• 560 Gt in above ground vegetation
• 1550 Gt in soil organic
• 807 Gt in the atmosphere
Soil Organic Carbon content in 1 m. (IPCC)
• 80 t/ha under crop lands
• 96 t/ha under temperate forests
• 123 t/ha under tropical forests
• 236 t/ha under temperate grasslands


Living Soil – the Foundation of Ecosystems
Important in ecosystems
Holistic science – Every Thing is linked with everything else
Humus – the bond between living and non-living parts in soil
Soil carbon – can be high on our 'old soils'
Abundant & Diverse Soil Food Web


Soil Management: Back to basics
• The soil is the foundation for crop and pasture and is the major determinant of risks and profits
• Soils in nature are living, self-organising systems
• Soil is considerably more complex and versatile than our mind can comprehend
• Every Thing is linked with everything else in time & space
Soil Organic Matter is at the Centre


Biological Functions
• home for soil organisms
• source of energy
• reservoir of nutrients
• contributes to resilience of system
Functions Organic Matter
Physical Functions
• improves soil structure, stability
• improves water holding capacity
• improves water retention
• alters soil thermal properties
Chemical Functions
• contributes to CEC
• buffering changes in pH
• complexes cations
• promotes binding of minerals
after Krull et al. 2004


Organic Matter
• Organic Matter is ~ 1.7 x Organic Carbon
Fraction of OM
• Dissolved OM
• Particulate OM, eg litter
• Humus, eg waxes, glues, humic acids, humin
• Inert OM, eg charcoal
Variability: extraction of soil sample
& analysis method

Carbon – C

The most important element in soil

- Soil Organic Carbon, eg. per 1%
  - +30 mm water available
  - +150 kg N/ha available
  - +125 $/ha productivity
- Soil Organic Carbon
  - home, storage & fuel for soil microbes
- Soil Organic Matter (incl. soil biology)
  - increases CEC
  - storage & availability for minerals

Carbon sequestration

Soil re-generation requires Carbon requires:

- Carbon in soil or on surface
- C:N:P:S availability in balance
- Fungi to decompose plant residues
- Bacteria to produce humic substances through bio-chemistry
- Soil biology to recycle carbon, being fed with root exudates, fresh carbon, from active plants.
- SOC potential depends on: Texture, Temperature & Rainfall

Living Soil

High Soil Organic Matter and Abundant & Diverse Soil Food Web slows Soil Evaporation

Higher water holding capacity And greater water retention

Carbon sequestration

Enhanced through management

- Protect & feed soil foodweb
- Cell grazing
- Maximise green, active cover
- No chemicals
- Minimum fertilisers

Minimum Tillage – stubble retention

- Under high input: stubble preserved – microbes killed by herbicides & alcohol formed under lack of oxygen.

Natural Soil Tillage: Worms

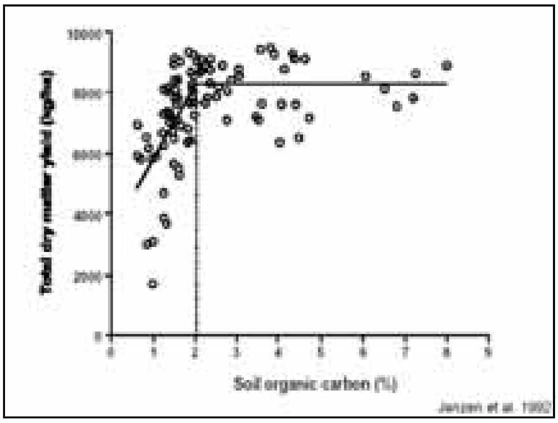
Healthy soil: 1-3 per spade

They ingest:

- Sand, silt, clay & minerals
- Dead plant material
- Microbes
- Nematodes
- Microanthropods

They excrete worm cast with:

- Organic matter
- Minerals
- Active microbes
- Pathogen suppression – reduce the 'bad guys'



Nutrients per 10cm

Rice Soil	% C	N	P	S
stubble retained	1.873	0.158	0.036	0.022
stubble burnt	1.096	0.095	0.023	0.012

Rice Soil	C (%)	N	P	S
stubble retained	1.0	0.0848	0.0192	0.0118
stubble burnt	1.0	0.0866	0.0208	0.0114
humus	*1.0*	*0.0833*	*0.0200*	*0.0143*

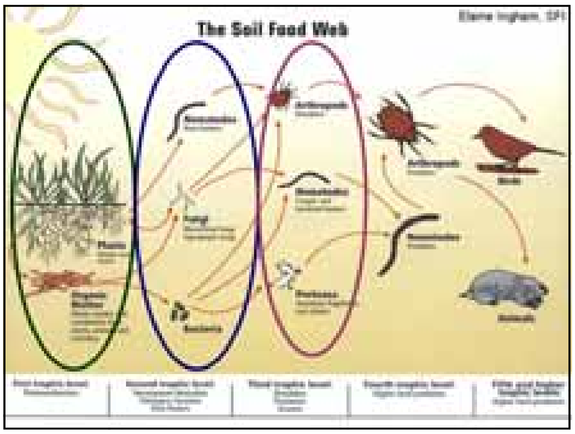
Clive Kirkby CLW

Carbon Sequestration

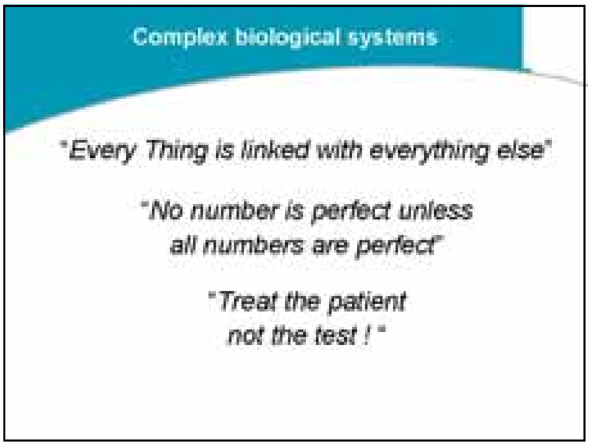
+1% C over 10cm = 1*10*1.4 = 14 t C/ha in 3 years
= 51 t CO_2/ha
= 17 t CO_2/ha/yr
car 15,000 km/yr = 3 t CO_2/yr

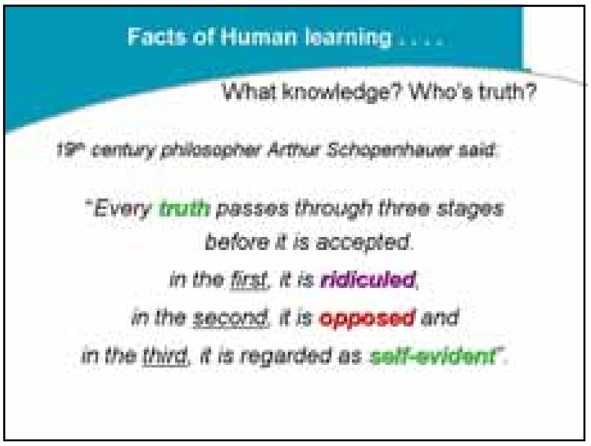
+1% C over 30 cm = 1*30*1.4 = 42 t C/ha in 6 years
= 154 t CO_2/ha

Leading science: 0.1 t C/ha ! ????




Soil Health Management
Thank You
With thanks to David Marsh, Christine Jones, Bev & Ron Smith, Colin Seis, Rhonda & Bill Daly, Brian Walker, Trevor Dawson, Adrian Lawrie, Tim Watt, Elaine Ingham, Arden Anderson, Amos Ferguson, Robert Bull, Jeptha Gates


Complex biological systems
"Every Thing is linked with everything else"
"No number is perfect unless all numbers are perfect"
"Treat the patient not the test ! "


Facts of Human learning . . . .
What knowledge? Who's truth?
19th century philosopher Arthur Schopenhauer said:
"Every truth passes through three stages before it is accepted.
in the first, it is ridiculed,
in the second, it is opposed and
in the third, it is regarded as self-evident".

Agriculture Notes

Healthy Soils in the Landscape

April 2005
AG1181
ISSN 1329-8062

Carole Hollier & Michael Reid, Rutherglen

Healthy soils support healthy plant growth, resist erosion, receive and store water, retain nutrients and act as an environmental buffer in the landscape. Soils supply nutrients, water and oxygen to plants, and are populated by soil biota which are essential for decomposition and recycling processes. Understanding, protecting and improving soil health is critical for managing Victoria's natural assets. In this context, soil health is therefore fundamentally linked to land productivity and environmental sustainability.

Managing soil health is essential to the long-term sustainability of your farm business. Maintaining soil health will maximise plant performance and prevent soil degradation. Agricultural viability depends upon healthy soil. As custodians of our soil resources every landholder has a duty of care to protect the soil asset for the next generation.

Chemical, physical and biological characteristics of soil are dynamic and they can change over time. Under pre-settlement conditions these characteristics changed very slowly. Following clearing the resulting land uses and management has radically altered some soil properties and in many instances has led to soil degradation and poor soil health.

There are many aspects that need to be considered when thinking about the "health" of your soil. Soil health issues are interrelated and so the soil should be treated as a system. The fundamental way to score the health of your soil is through comprehensive soil testing and analysis. There are a range of "fee for service" providers, including the Department of Primary Industries (DPI) where testing is done according to national accreditation standards.

Soil testing is essential for whole farm planning. Surface and subsurface soil testing is a basic business operation and should be done regularly (annually to every five years, depending on your enterprise program) as a diagnostic, monitoring and evaluation/planning tool. Multiple tests may be required to cover variation across paddocks and landscape types on the farm (Agnote: AG0375, AG0376).

Good interpretation of soil test results is essential in making the right management decision and will depend on the context of your production goals and enterprise mix. DPI can provide guidelines to assist in soil health interpretation and agronomic advice. Decisions to protect and maintain soil health need to take both short and long term approaches and involve decisions about crop rotations, pasture species, stock management, traffic control, choice of soil fertilisers and conditioners and their application rates..

Good soil health is all about creating a robust soil that can provide all the needs of the production system and withstand impacts or recover quickly without loss of fertility, structure or biological activity. The physical, chemical and biological features of soil interact and need to be managed with this in mind.

Acid Soils

For example, **soil acidity** can influence soil health and impact on plant growth and persistence (Agnote:AG1182). Soil pH is a measure of acidity and alkalinity. A pH of 7 is neutral, above 7 alkaline and below 7 acid.

Some plants prefer acid soil conditions while others prefer alkaline conditions. Soil acidity affects the availability of nutrients in soil. In acid soils (low pH) some elements become available to plants in amounts that are toxic (for example, aluminum), while other useful elements become locked away and are unavailable (for example, molybdenum). Bacterial populations generally prefer a slightly acid environment, however highly acidic soils can inhibit the survival of useful bacteria, for example the rhizobia bacteria that fix nitrogen for legumes. As the soil acidifies, the favorable environment for bacteria, earthworms and many other soil organisms is degraded.

Fungi are an exception to this and often prefer acid soils. Many essential nutrient cycles are completed through bacterial interactions, more so than through fungal activity. Low soil pH will impact on the structural properties of the soil (mineral breakdown) and influence the populations of earthworms and other beneficial soil organisms.

Victoria
The Place To Be

Acid soil management is part of a sound overall environmental management approach for the farm business. It can be managed effectively by lime application before acidification becomes too severe. Liming is good risk management and insures against losses due to poor plant nutrition, but may not always be profitable. Decisions to lime need to be taken within the context of the whole farm plan and enterprise options. Lime treatment varies in its effectiveness depending on the quality of the lime and the application method.

Many soil health problems occur as result of natural processes (for example, soil acidification), however land use practice can also positively influence soil health (for example, planting perennial systems to prevent excess water leakage and reduce salinity). Farms may have a variety of soil types that require specialised management to optimise soil health, productivity and prevent land degradation. Different soil attributes reflect different geology, climatic conditions, and position in the landscape (Refer to Agriculture Notes: AG1182 – Acid Soils).

How do we improve our soil health?

Indicators and diagnostics:

Improving soil health can be achieved by looking at various plant health and performance indicators. Poor soil health can be seen through the visual clues of poor plant growth (for example, wilted or stunted plants). Plants growing in poor soils could also be susceptible to disease and may have leaf discolouration or spots and die-back.

Visual clues in the paddock may indicate conditions that lead to poor soil health. Inspection of surface appearance can reveal crusting and surface sealing, loose grain or sediment material, aggregation of clods, evidence of erosion, compaction, pugging and surface deposits like salt or algae.

Testing samples of roots or tissue may indicate nutrient or elemental deficiencies in the soil that result in yield depression. Chemical tests of soils will reveal levels of major nutrients, such as nitrogen, phosphorus or potassium.

Through careful excavation, examination of soil structure, root penetration and distribution, soil colour, strength of horizons, and odour may indicate poor soil condition. Penetration resistance can be assessed by probing hardpans or dense layers with specialised mechanical tools.

Management responses:

Improved soil health can be achieved by active management and the introduction of soil conditioners and ameliorants such as lime, gypsum and fertilizers. Soils will respond to incorporation of organic matter through improved stubble management and grazing practice.

Green manure crops and other imported animal manures or biosolids can be used, but caution should be taken to avoid contamination. Landholders should seek analysis information about any conditioner, prior to use.

Landholders can improve soil performance by physical actions such as limiting heavy machine traffic, where possible. Loosening of sub-surface layers may be necessary where compaction has occurred. Careful cultivation to remedy sealing, pugging and trampling may provide positive soil responses and plant growth.

Well designed raised bed formation will deliver drainage benefits under some heavy soil conditions and paddock spelling or a pasture phase following cropping can enhance recovery of crop growing conditions.

The following Agnotes may assist landholders with field sampling procedures for soils and other produce:

Agnote AG0375: Sampling soils for growing pastures, field and fodder crops

Agnote AG0376: How to sample soils used for flower, fruit, grape and vegetable production.

Agnote AG0198: Collecting samples for nematode analysis of citrus and grapevines.

Agnote AG0889: Guidelines for sampling soils, fruits, vegetables and grains for residue testing.

All Agnotes are located at: http//www.dpi.vic.gov.au

Search for 'Agnotes' and follow the prompts.

Testing of samples can be arranged at Primary Industries Research Victoria – Werribee Centre

Department of Primary Industries

621 Sneydes Road Werribee VIC 3030

Telephone: **(03) 9742 8755**

Facsimile: **(03) 9742 8700**

Contact the relevant Section Leader (Inorganic Chemistry for soils testing and Organic Chemistry for pesticide testing) for test specifications and pricing details, prior to sending samples.

Agriculture Notes

Acid Soils

Carole Hollier & Michael Reid, Rutherglen

April 2005
AG1182
ISSN 1329-8062

Why Worry About Acid Soils?

Soil acidity is a natural and induced chemical condition of soils that can:

- decrease the availability of essential nutrients;
- increase the impact of toxic elements;
- decrease plant production and water use;
- affect essential soil biological functions like nitrogen fixation; and
- make soil more vulnerable to soil structure decline and erosion.

The process of soil acidification is a potentially serious land degradation issue. Without treatment, soil acidification will have a major impact on agricultural productivity and sustainable farming systems and acidification can also extend into subsoil layers posing serious problems for plant root development and remedial action.

In some regions, there has been a drop of one pH unit over the last 20 to 30 years. Already, some farming areas have lost the ability to grow preferred agricultural species such as phalaris and lucerne simply because, without lime, the soil is too acid.

Understanding Soil Acidity

Soil acidity occurs naturally in higher rainfall areas and can vary according to the landscape geology, clay mineralogy, soil texture and buffering capacity. Soil acidification is a natural process, accelerated by some agricultural practices (**Figure 1**).

When plant material is removed from the paddock, alkalinity is also removed. This increases soil acidity. When grain, pasture and animal products are harvested from a paddock, the soil is left more acid. Hay removal is particularly acidifying because large amounts of product are removed.

More significantly, soil acidification is most often a result of nitrate leaching. Nitrogen is added to the soil in a number of ways:

- nitrogen fixed by legume-based plants;
- as nitrogen based fertilisers;
- from breakdown of organic matter; and
- dung and urine.

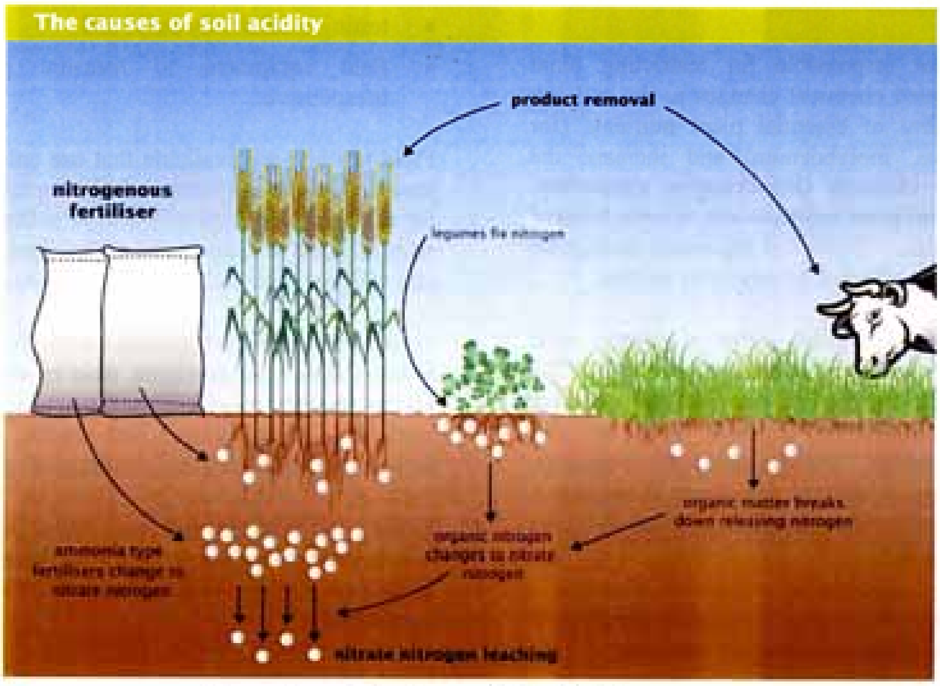


Figure 1: The Causes of Soil Acidity

Acidification occurs in agricultural soils as a result of the:

- removal of plant and animal products;
- leaching of excess nitrate;
- addition of some nitrogen based fertilisers; and
- build-up in mostly plant-based organic matter.

Soil pH

Soil pH is a measure of acidity or alkalinity. A pH of 7 is neutral, above 7 is alkaline and below 7 is acid. Because pH is measured on a logarithime scale, a pH of 6 is 10 times more acid than a pH of 7. Soil pH can be measured either in water (pH_w) por in calcium chloride (pH_{Ca}) and the pH will vary depending on the method used. As a general rule, pH measured in calcium chloride is 0.7 of a pH unit lower than pH measured in water (**Figure 2**). When a laboratory measures your soil's pH it is important that they specify which method (water or calcium chloride) was used.

For most acid soils, the most practical management option is to add lime to maintain current soil pH status or increase surface soil pH.

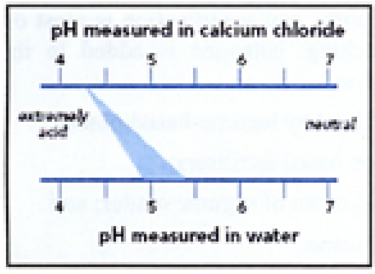


Figure 2: Relationship between pH measured in Calcium Chloride and Water

The Acid Attack

Acidity itself is not responsible for restricting plant growth. The associated chemical changes in the soil can restrict the availability of essential plant nutrients (for example, phosphorus, molybdenum) and increase the availability of toxic elements (for example, aluminium, manganese). Essential plant nutrients can also be leached below the rooting zone. Biological processes favourable to plant growth may be affected adversely by acidity.

Bacterial populations generally prefer a slightly acid environment. However highly acidic soils can inhibit the survival of useful bacteria, for example the rhizobia bacteria that fix nitrogen for legumes. As the soil acidifies, the favorable environment for bacteria, earthworms and many other soil organisms is degraded. Acid soils have a major effect on plant productivity once the soil pH_{Ca} falls below 5:

- pH_{Ca} 6.5 - optimum for most plant growth; neutral soil conditions; some trace elements may become unavailable.
- pH_{Ca} 5.5 - balance of major nutrients and trace elements available.
- pH_{Ca} 5.0 - aluminium may become soluble in the soil depending on soil type; phosphorus combines with aluminium and may be less available to plants.
- pH_{Ca} 4.5 - manganese becomes soluble and toxic to plants in some soils; molybdenum is less available; soil bacterial activity slows down; aluminium becomes soluble in toxic quantities.
- pH_{Ca} 4.0 - soil structural damage begins to occur.

Soil pH will influence both the availability of soil nutrients to plants and how the nutrients react with each other. At a low pH many elements become less available to plants, while others such as iron, aluminum and manganese become toxic to plants and in addition, aluminum, iron and phosphorus combine to form insoluble compounds. In contrast, at high pH levels calcium ties up phosphorus, making it unavailable to plants, and molybdenum becomes toxic in some soils. Boron may also be toxic at high pH levels in some soils.

The relative availability of 12 essential plant nutrients in well-drained mineral soils in temperate regions in relation to soil pH is shown in **Figure 3**. A pH_{Ca} range between 5 and 6 (between heavy lines) is considered ideal for most plants.

Understanding Soil pH by Testing

Soil pH is one of the most routinely measured soil parameters. It is used as a benchmark to interpret soil chemical processes and governs the availability of many essential or toxic elements for plant growth.

Soil pH is a common measure of the soil's acidity or alkalinity because:

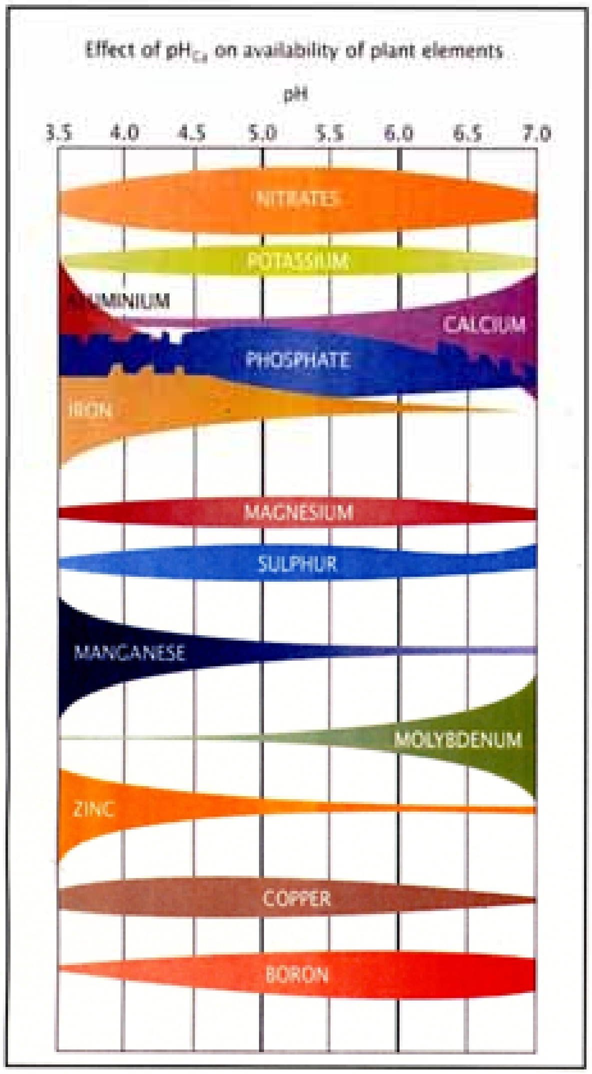
- testing is relatively easy; and
- field equipment to measure pH is relatively inexpensive.

Field test kits are available that use colour to indicate pH levels. The kits are inexpensive, easy to use and will test a lot of samples but should not be relied on for decisions such as rates of lime application. Test kits will only tell you whether your soil is acid or alkaline.

A number of compact testing meters that can be used out in the paddock are available, most of which are capable of giving accurate results if used correctly. Professional soil analysis is recommended and sending soil samples to a recognised laboratory ensures the most accurate results.

Testing of both topsoil and subsoil is recommended. When interpreting plant responses based on soil pH, the surface (A horizon) and sub-surface (B horizon) need to be considered.

Figure 3: Effect of pH_{ca} on the availability of plant elements.



The soil pH_W is considered to be closer to the pH that the plant roots experience in the soil. But it is subject to large variation within the paddock because of seasonal changes in soil moisture and the ionic concentration of the soil solution that is related to the amount of total salts in the soil.

Research has shown that seasonal variation of pH_W can vary up to 0.6 of a pH unit in any one year. In comparison, the measurements of soil pH_{Ca} is less affected by seasons.

Farmers can take soil samples at different times during the year without affecting the final diagnosis or interpretation.

Soil pH_{Ca} measurements in Australia vary from pH_{Ca} 3.6 to pH_{Ca} 8 for a range of different soil textures (sandy loams to heavy clays). Soil pH_W values lie between pH_W 4 and pH_W 9.

Higher pH_W values to around 10 may be associated with alkali mineral soils containing sodium carbonates and bicarbonates.

Some Useful Tips......

- Soil pH is measured in either water or in calcium chloride. When measured in calcium chloride, the result is lower than pH measured in water.
- The pH_W may be higher by 0.6 to 1.2 in low salinity soils and higher by 0.1 to 0.5 in high salinity soils. Research has shown a difference of 0.7 for a wide range of soils.
- Soil testing will tell you the current acidity status of your paddock. If your soil pH_{Ca} is above 5.5 then there is little immediate risk of acidity.
- Lime can restore productivity in acid soils and should be considered once the pH drops below pH_{Ca} 5.0 if sensitive species are to be grown successfully.
- You are unlikely to get responses to lime if other nutrients are lacking. This should show up in a soil test or plant tissue analysis and should be corrected. Conversely, you may not get a response to some nutrients if the soils are too acid. A holistic balanced approached is necessary.
- Lime responses are generally seen in the first and second year for cropping systems, but can take up to five years depending on soil type, rainfall and lime quality for permanent pasture systems.
- It is necessary to re-lime your paddock about every 10 years, depending on the rate of re-acidification.
- If paddocks with an acidity problem are not limed, the soil pH will continue to fall and settle at pH_{Ca}3.8 to 4.2.
- The amount of lime you need to apply varies according to soil type. Field experiments have shown that up to 5 tonnes a hectare on clay loams and 1.5 tonnes a hectare on sandy soils is needed to increase pH by one unit.
- Lime moves slowly (0.5 to 1cm per year) through the soil profile via the soil macropore structure. Incorporation into the soil profile, where possible, will assist effective treatment.
- In permanent pasture situations, spreading the lime on the surface and allowing it to work its way into the soil is acceptable. Surface application is better than no application.

The following Agnotes may assist landholders with field sampling procedures for soils:

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FAST FACTS .... SOIL HEALTH

ADVANCE AUSTRALIA FAIR

Australians all let us rejoice
For we are young and free;
We've golden soil and wealth for toil;
Our home is girt by sea;
Our land abounds in nature gifts
Of beauty rich and rare;
In history's page let every stage
Advance Australia fair;
In joyful strains then let us sing
"Advance Australia fair."

By Peter Dodds McCormick

In order to Advance Australia fair as a nation and individuals. We need to take the topic of soil health seriously and invest resources in better understanding what healthy soil is and **how we can improve it?**

WHAT IS A HEALTHY SOIL?

A healthy soil is a **living renewable resource** that has the ability to increasingly reproduce itself in the form of topsoil in a sustainable manner. If a soil can't reproduce itself it is simply not self sustaining.

What is Soil Health?

Soil health is a measure of a soil's vitality to renew and increasingly reproduce itself in the form of topsoil over a two to five year period. For example, a healthy soil "grows" topsoil and stores carbon.

Sick soil has a net loss of soil & carbon due to accelerated erosion and associated agricultural production. This is often linked with declining soil structure, low biodiversity, poor water holding capacity and low agricultural productivity.

SIX ENEMIES OF SOIL HEALTH

Soil health relates to the chemical, physical & biological components in the soil. Soil health and soil biology can be degraded by chemical imbalances through excesses in sodium, hydrogen and chemical residues.

3 EXCESSES

Salinity	[excess of Sodium]
Acidity	[excess of Hydrogen]
Contaminates	[excess of Chemical Residue]

When dealing with excess. I.D. & know your enemy.
For acidity consider soil tests that document assumed Hydrogen levels 4.6 pH = 53% H & 5.6 pH = 27% H

The next three enemies involve the physical components of the soil, especially as soil aggregation breaks down.

Soil Erosion: Soil particles detachment & transportation
Soil Structure Declining: Lack of aggregation pattern.
Soil Compaction: Lack of Oxygen & pore space

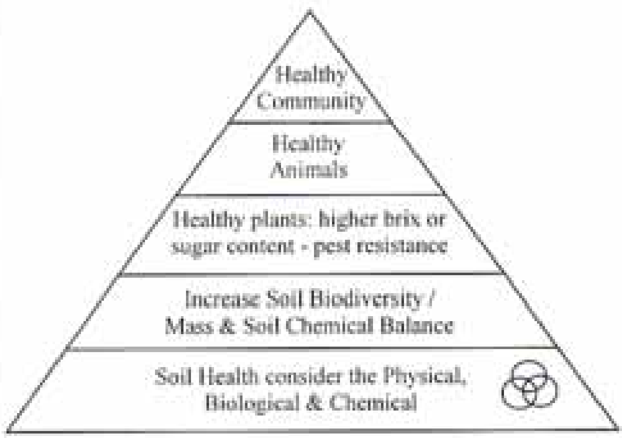
THREE KEY PRINCIPLES

Conserve the soil that you have via erosion control.
Cover the soil surface: Min 70% groundcover, particularly over summer [ideally 100% earthworm castings]. Preference for deep rooted perennials over annuals. With regards to cropping the use of crop rotation would be preferred with minimum tillage / soil disturbance, stubble retention and minimum stubble burning.
Grow Topsoil - maximise leaf & root surface area. Optimum Stocking Rates for Land Classification. Rotational [Time] Grazing [Min Set Stocking]. Balance soil cation ratios Calcium / Magnesium & K / Na. Minimum of 5.6 pH [Water] = 27 % Hydrogen. Identify what form of Calcium to use - Rock Phosphate, Lime, Dolomitic Lime, Dolomite or Gypsum. Minimum 1-2 earthworms per shovelful [Winter / Spring]. Improve soil biology > plant succession > humus formation.

THE SOIL FERTILITY SPIRAL

Yield, Quality, Income ⇑ Capital for Investment ⇑
Increase in topsoil depth, Water retention, Nutrient ↻
Soil fertility ⇑ Succession of voluntary plants species
Increase active humus ⇑ [C.E.C.⇑, nutrient retention ⇑]
Biomass ⇑ Protein level ⇑ C to N⇑ Decomposition ⇑
Soil biodiversity ⇑ = Earthworms, better smelling soil
Amount/size of soil pore space [porosity] ⇑ Biohomes⇑
Soil aggregation ⇑ Soil structure [pattern of aggregation]⇑
Root exudates⇑ Biochemical signals symbiotic relations⇑
START → **Root mass and decomposition** ⇑ Plant yield /quality ⇑
Soil Erosion = Soil particles detachment & transportation ⇩
Soil Organic matter & colloidal material [Clay/Silt] ⇩
Detachment occurs: Soil aggregates breakdown ⇩
Reduction in soil [porosity] pore spaces ⇩
Soil becomes compacted & surface crust forms ⇩
Increase in transport [wind & water] velocity ⇩
Increase loss of topsoil & organic matter, Nitrogen ⇩
Pasture/Crop yields ↓ [negative economic signal] ⇩
Less income to reverse soil health decline
Potential loss of "Capital" in Topsoil & Land Values.

Soil Health The **Gate Way** to Healthy Farming



The choice is clear - Develop improved Soil Health Strategies or allow our economic sustainability to be eroded away.

 Contact: Gwyn Jones 042 776 1191 or **gjones@healthyag.com**

References: D.N.R.E., 2001, Draft North East Soil Health Action Plan, D.N.R.E., Rutherglen / Acton, D.F., & Gregorich, L.J., 1995, *The Health of Our Soils*, C.L.B.R.R., Ottawa.

HOW TO BECOME A BETTER BIOLOGICAL FARMER

Focus on: Synthetic CHEMICALS* Inputs: Insecticides Fungicides Herbicides Urea DAP, S/Super Sulphate of Potash * Is there use, treating the symptom or the problem?	The Missing Link: Focus On Minerals Treat the Problem Not the Symptom	Focus on: BIOLOGICAL Inputs: Fish emulsion Beneficial bugs in a bottle VAM Is soft Lime: Biological [?]	Focus on: ENERGY Inputs: Paramagnetic Rock Magnets Homeophothy

A diagrammatic way to illustrate the MINBIEN [**Mine**ral, **Bio**logical and **En**ergy] inputs and management systems is as follows:

MINERAL BIOLOGICAL ENERGY

MINERAL	BIOLOGICAL	ENERGY
ADDED INPUT CALCIUM Rock Phosphate Lime Dolomitic Lime Dolomite Gypsum Copper, Zinc, Boron, Manganese, Se, Mo etc..	ADDED INPUT BOTTLED BUGS [COMPOST TEA] Probiotics	ADDED INPUT PARAMAGNETIC ROCK [Si] HOMEOPHOTHY Biodynamic methods *Substance* v's *Force*
CHANGE AVAILABILITY Liming acid soil: P, Mo & N ⇑ Al, Fe, Cu, Mn & Zn ⇓	CHANGE AVAILABILITY ADD SUGAR ADD MOLASSES Liming acid soil: Aeration: Oxygen ⇑	CHANGE AVAILABILITY Use of Magnets Paramagnetic Level ⇑

1st STOCKING RATE

2nd GRAZING METHOD

Ryegrasses White Clover Sub Clover Low Fert Grasses Native Grasses

Management Strategies for Growing Topsoil

Aim: To optimise - soil fertility, [voluntary] plants species succession & plant yield

ASSESS **PLANT SPECIES SUCCESSION** [The Soil Builders]: See Sheet

⇩

ASSESS **HARVESTING METHODS** by plants and of the plants

Aim: Increase leaf/root surface area to make the unavailable [air/water/minerals], available

Review: Stocking Rate 1st & Grazing Method 2nd or Pruning, Slashing, Mowing etc]

Review: DIY SoilHEALTH; Physical & Biological Audit: See Sheet

PA YEOMANS SHORT CUT

⇩

ASSESS **SOIL CHEMISTRY**: Do you add or change the availability

Aim: To balance soil chemistry: N,P,K,S & balance the cations: Ca/Mg, K/Na & H Base Saturation

Aim: pH > 5.6 - 6.2* [in Water] *Beware of speciality crops. Don't apply "Lime" solely on soil pH.

⇩

Calcium : **Mg**nesium Ratio? [~~1,2,3~~,4*,5*,6*,~~7~~,8 Ca: 1 Mg Base Saturation - *Depending on Lab]

Is Calcium needed? Is Phosphorous also needed? If Rock Phosphate is needed, use it before Liming

⇩

1st Choose a Calcium Source [+ P or @33/1 Mg, @5/1 Mg, @2.5/1 Mg or S] if needed

Ca 22% + P 15% = Rock Phosphate	Ca 33% + Mg 1% = Lime: 33Ca / 1Mg	Ca 30% + Mg 5% = Dolomitic Lime:5Ca/1Mg	Ca 25% + Mg 10% = Dolomite: 2.5 Ca / 1Mg	Ca 23% + S 18% = Gypsum

Less Needed if RRP used? Less pH change

Can Induce Se deficiency?

⇩

Make your selection first before you consider ENV*

Don't buy "Lime" only on *Effective Neutralising Values

2nd Assess ENV* [Transport $]

⇩

Assess Mineral Interactions & Trace Element Requirements [Cu, Zn, Mn & *B* etc as pH changes]

⇩

REVIEW **SOIL PHYSICS**: Consider mechanical soil aeration: See Fast Fact Sheet:

a] Is there a problem? eg a hard pan [Use a penetrometer?] Which aeration tool to use? Or

b] To enhance topsoil development [to compressing time?]

⇩

REVIEW **SOIL BIOLOGY** [The Recycle Team]: See Fast Fact Sheet:

a] Stimulate Existing Biology [Improve conditions? Do you feed them?] Or

b] Adding "Better Bugs" to your seed 1st & soil 2nd [to compressing time]?

⇩

ASSESS **SOIL ENERGY** = Big 3: C / O / Si [Storage of energy like a car battery]

a] Improve General Vitality [using Radionics?] by eg Mechanical Aeration [**O**] Or

b] Adding paramagnetic material: Rock Dust [**Si**] or Carbon [to compressing time]

⇩

REVIEW **CARBON SEQUESTRATION** [The Warehouse /]: "Active" Humus coating original soil particles, making a younger renewable soil resource. Growing Topsoil is the by-product!

⇩

REVIEW **PLANT SPECIES SUCCESSION**:

a] Improve plant species/succession – review harvesting methods by & of plants? Or

b] Adding seed [Cropping]: Direct sowing –perennials, if they are present [to compressing time]?

CORRELATION OF PLANT SUCCESSION & SOIL FERTILITY

A Hierarchy of 56 Naturalised* Indicator Pasture Species in N.E. [Victorian] Acid Soils

Accumulator Plants

< Indicating 1st Low Phosphorus & 2nd Low Calcium [Need both R.R.P.?] >

Native:			**Original Species**
Spear	Grass		Stipa spp
Windmill	Grass		Chloris truncata
Kangaroo	Grass		Themeda spp
Red[-leg]	Grass		Bothriochloa macra
Weeping	Grass		**Microlaena** stipoides
Wallaby	Grass		Danthonia spp
Wheat	Grass		Elymus scaber
Soil fertility Class: LOW			**Pioneer Volunteer Species**
Mosses / Liverworts		Common Communities	Bryophytes spp
Toad	Rush	" "	Juncus bufonius
Winter	Grass	" "	Poa annua
Common	Rush	" "	Juncus polyanthemos
Spiny	Rush		Juncus acutus
Sorrel [Sheep]			Rumex acetosella
Onion Weed	/ Guilford Grass		Romulea rosea
Trifolia & Medics	Eg Cluster Clover		Trifolium glomeratum
Summer	Grass		Digitaria sanguinalis
Meadow Foxtail	Grass		Alopecurus pratensis
Soft Broome	/ Goose Grass		Bromus mollis
Flat Weed	/ Cats Ear	Common Communities	Hypochoeris radecarta [Hairs on top of leaf]
Bent Grass	/ Browntop	" "	Agrostis capillaris
Rib Grass / Ribwart	Plantain	" "	Plantago lancealata
Broad Leaved	Plantain		Plantago major [What's the 3rd one?]
Sweet Vernal	Grass		Anthoxanthum odotatum
Crested Dogstail	Grass		Cynosurus critatus
Ratstail	Grass		Sporobolus capensis
Rat Tail / Slender Fescue			Vulpia bromoides

<Need Ca: Lime? or Ca & Mg: Dolomitic Lime, Dolomite? >

Soil fertility Class: MEDIUM			**Opportunist Species**
Annual / Wimmera	Ryegrass	Common Communities [Lower Rainfall]	Lolium rigidum
Mt Barker, Clare etc	Sub Clover	" "	Trifolium subterraneum
Barnyard	Grass		Echinochloa crus-galli
Tall Fescue			Festuca arundinacea
Tall Wheat	Grass	Common Communities [Wetter Areas *]	Aropyron elongatum $
Strawberry	Clover	" " .	Trifolium fragiferum $
Red [Fiddled]	Dock	" " .	Rumex pulcher
Swamp * Curled	Dock	" " .	Rumex brownii / crispus
Yorkshire Fog	Grass	" " .	Holcus lanatus
Prairie	Grass		Bromus unioloides

Exploitive Plants

Soil Fertility Class: HIGH			**Advanced Species**
Phalaris			Phalaris tuberosa
Kikuyu			Pennistetum clandestinum
Timothy	Grass		Phleum pratense
Cocksfoot			Dactylis glomerata
Paspalum			Paspalum dilatatum
Chicory			Cichorium intybus
Dandelions		Common Communities	Taraxacum officinale [No hairs on leaf]
White	Clover	" "	Trifolium repens
Perennial	Ryegrass	" "	Lolium perenne
Red	Clover	[Not naturalised* - No Bumble Bees]	Trifolium pratense
Lucerne			Medicago sativa

Accumulator Plants

< Need Ca? & Biology >

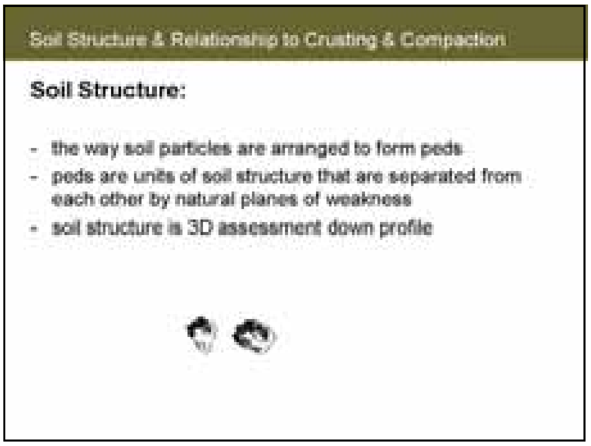
Is Sugar/Carbohydrates Needed?

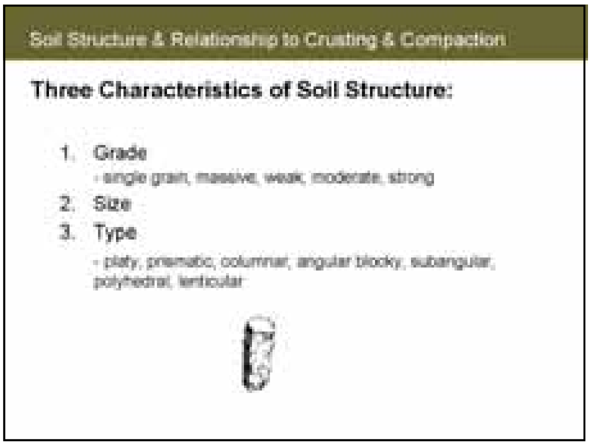
Soil Fertility Class: EXCESS			**[C/N Ratio. Is Nitrogen ⇧?]**
Barley Grass			Hordeum leporinm
Capeweed			Arctotheca calendula
Fat Hen	/ Goosefoot		Chenopodium album
Wire Weed	/ Knotgrass		Polygonum aviculare
[Tree] Hog Weed			Polygonum patulum
Marsh Mellow		Common Communities	Melva parviflora
Prince of Wales Feather		" "	Amaranthus refetroflexus
Black Nightshade		" "	Solanum nigrum
Common Stinging Nettle		" "	Urtica dioica [☐ Si accumulator?]

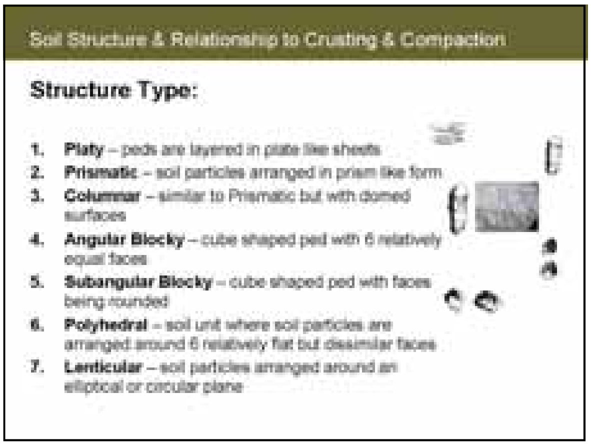
© Integrated Agri-Culture P/L 2006 with assistance from Jack Jones for local Mudgegonga pasture species.

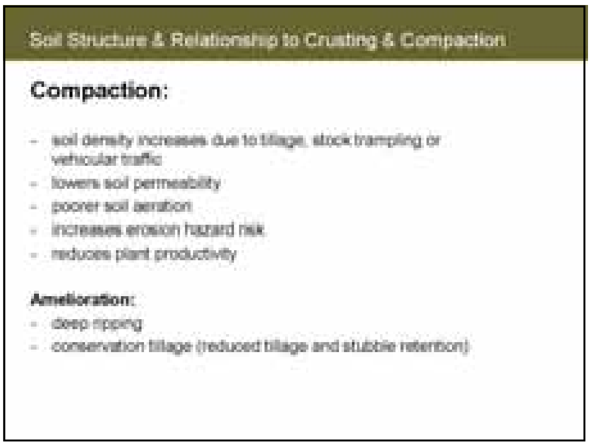
The information contained in this publication has been formulated in good faith, the contents do not take into account all the factors which need to be considered before putting that information into practice. Accordingly, no person should rely on anything contained herein as a substitute for specific professional advice. Rev 5.5, 2006 **gjones@healthyag.com** Gwyn Jones +61 7 5580 8181

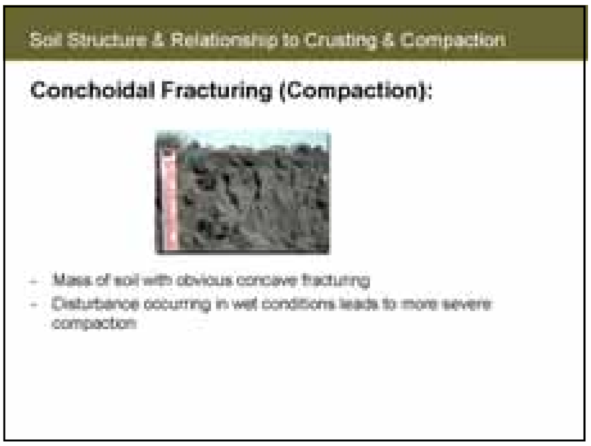

Soil Structure & Relationship to Crusting & Compaction
Keith Reynard - PIRVic
24th July, 2007


Soil Structure & Relationship to Crusting & Compaction
Soil Structure:
- the way soil particles are arranged to form peds
- peds are units of soil structure that are separated from each other by natural planes of weakness
- soil structure is 3D assessment down profile


Soil Structure & Relationship to Crusting & Compaction
Three Characteristics of Soil Structure:
1. Grade
- single grain, massive, weak, moderate, strong
2. Size
3. Type
- platy, prismatic, columnar, angular blocky, subangular, polyhedral, lenticular


Soil Structure & Relationship to Crusting & Compaction
Structure Type:
1. Platy – peds are layered in plate like sheets
2. Prismatic – soil particles arranged in prism like form
3. Columnar – similar to Prismatic but with domed surfaces
4. Angular Blocky – cube shaped ped with 6 relatively equal faces
5. Subangular Blocky – cube shaped ped with faces being rounded
6. Polyhedral – soil unit where soil particles are arranged around 6 relatively flat but dissimilar faces
7. Lenticular – soil particles arranged around an elliptical or circular plane


Soil Structure & Relationship to Crusting & Compaction
Compaction:
- soil density increases due to tillage, stock trampling or vehicular traffic
- lowers soil permeability
- poorer soil aeration
- increases erosion hazard risk
- reduces plant productivity
Amelioration:
- deep ripping
- conservation tillage (reduced tillage and stubble retention)


Soil Structure & Relationship to Crusting & Compaction
Conchoidal Fracturing (Compaction):
- Mass of soil with obvious concave fracturing
- Disturbance occurring in wet conditions leads to more severe compaction

Soil Structure & Relationship to Crusting & Compaction

Crusting:

- soils with a massive or weakly structured surface crusty horizon
- often lower in clay content than underlying non self mulching structured clay

Soil Structure & Relationship to Crusting & Compaction

Dispersion:

Left dish displays topsoil (non dispersive) and subsoil (dispersive). Right dish shows soil immersed in gypsum.

Remoulded soil aggregates. Replicates effect of cultivation.

Soil Structure & Relationship to Crusting & Compaction

Dispersion:

- is the structural breakdown of soil aggregates in water
- dispersed clays block micropores & macropores
- surface seals & hardpans are often indication of soil with dispersible clay
- restriction of root penetration into subsoil
- chemical process where negatively charged clay particles react with positively charged sodium ions
- soils of > 6% Na are known as Sodic soils

Soil Structure & Relationship to Crusting & Compaction

Management:

- apply gypsum (Ca replaces Na to flocculate clay particles and form stable aggregates)
- include deep rooted crops in rotation
- minimum tillage techniques
- maintain vegetative cover on soil surface year round such as retained stubble or pasture cover
- avoid cultivating soil when moist