Biological Farming Systems Soil Carbon Tour (BFSSCT)

Vic - 6th August 2009

Based on Tour Booklet from BFSSCT held 11-12 May 2009

Revised Version 4th August 2009

The tour hosts are
Ignite Energy Resources Director, Dr John White & LawrieCo Managing Director, Adrian Lawrie.

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REPORT FROM BioLogic Farming Systems Soil Carbon Tour (BFSSCT) 25th May 2009

Held on 11th & 12th May 2009 – Central SA and South West Vic

The BFSSCT highlighted the potential contribution of agriculture, using biological farming systems (BFS), to reduce Greenhouse Gas (GHG) emissions and sequester atmospheric carbon dioxide into soil organic carbon (SOC), providing the option to offset Australia's emissions over the next 40 years.

Estimates are that a 1% increase in soil carbon in just 10% of Australia's farmland could remove 10 years' worth of Australia's carbon emissions while a 4% increase in soil carbon could remove 40 years' worth.

In addition, increasing soil carbon levels has economic benefits - the potential to increase productivity, improve drought and salinity resistance, and to reduce the need for costly inputs (chemical fertilisers, insecticides/ pesticides and animal drenches, et al – which will yield healthier food and fibre).

Currently there are over 300,000 hectares in Australia using BFS, indicating the additional benefits to agricultural production over and above building SOC and CO_2 sequestration.

These benefits reduce the cost of the carbon offsets, thus providing Australia with a low cost, environmentally beneficial pathway to a low carbon economy – a '**Carbon Bridge**'.

BFSSC Tour Details

Australia's former Governor General, Major General Michael Jeffery acted as patron to the tour, based on his personal interest in highlighting the imperative to remediate Australia's agricultural landscape.

Over sixty persons including scientists from University of Adelaide, DPI; leaders of carbon farming organizations; as well as investors and business leaders from companies such as Woodside Energy Ltd, The Griffin Group and Australian Agricultural Company (Australia's largest agricultural landholder) took part in the tour.*

Eight properties using BFS were visited over 2 days throughout central South Australia and South West Victoria, covering various agricultural industries: broad acre continuous cropping, pasture, dairy, raised bed cropping and viticulture.

The tour was hosted by Ignite Energy Resources Director, Dr John White, and LawrieCo founder and Managing Director, Adrian Lawrie.

Key Points from BFS Properties Visited*

1. Reduced fertiliser use
   - Up to 85% reduction in use of Nitrogenous fertiliser, reducing relative Nitrous Oxide (GHG)emissions
   - Over 70% reduction in use of chemically treated phosphate fertiliser
2. Reduced incidence of pest and disease and subsequent use of insecticide/ fungicide sprays
3. Soil Organic Carbon increases up to 1.2% over 3 years and maintained with continuous cropping
4. Healthier stock (requiring less veterinary attention and mineral supplementation)
5. Pasture quality improvements, including species mix and resistance to dry periods
6. Soil water infiltration and holding capacity improved - drought proofing in dry years
7. Building soil fertility index – mineral balance, biological activity and physical structure and friability
8. Return of natural soil biota – dung beetles, earthworms, beneficial bacteria and fungi et al
9. Higher quality produce with maintained or greater production levels

Post Tour Outlook

A carbon farming approach will benefit significantly the agricultural sector by improving soil quality and hence yields, and by reducing input costs with less need for synthetic chemical fertilisers and insecticides/pesticides. This system should incorporate aspects of Natural Sequence Farming, biological fertiliser use and the adoption of rotational grazing.

Australia should adopt an objective of the conversion of 80% of all Australia's agricultural and range lands to appropriate natural science farming methods (including Biological Farming Systems) by 2020 – to bio-sequester 300 million tonnes of CO_2 equivalent per annum.

To facilitate the achievement of this Vision, it was recommended that a small Sustainable Farming Taskforce be established to oversee its strategic implementation. It is envisaged that this Taskforce would report at a Federal level to the Prime Minister's office and to the States via the Council of Australian Governments.

For Further Information on the BFSSCT Contact:

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Dr John White, Ignite Energy Resources 03 8600 7000 john.white@igniteer.com

*Participant biographies and individual BFS property details are available in the tour booklet, available from LawrieCo.

Biological Farming Systems - CO_2 Sequestration Estimate & N_2O Reduction

Biological Farming Systems (BFS) is a pursuit of agricultural practices that creates soil mineral balance, promotes organic soil carbon and increases healthy soil biota to ensure sustainably productive soils.

Background

Australia's rangelands (tropical savannas, temperate woodlands, shrublands and grasslands used for extensive grazing) are estimated to comprise approximately 288M hectares. The land areas devoted to more intensive agricultural production comprise approximately 167M hectares (National Land and Water Resources Audit). The estimate below uses Australia's cropped area of 24.7M hectares which is dry land and irrigated area.

Cropping is therefore a relative small component of what could be achieved across all agricultural land use. An important example though, as CO_2 emissions in cropping currently is high and increasing because of fertiliser, chemical and diesel use as easy solutions to production problems.

CO_2 Sequestration Estimate

Table 1 illustrates the significant quantity of atmospheric CO_2 that can be sequestered per annum (by plant photosynthesis via the plant roots structure and biological/chemical interactions) by a given agricultural area adopting BFS with an absolute soil carbon increase of 0.15%. This increase is conservative and realistically achievable by adopting BFS. BFS field results have shown soil carbon to increase by 1.2% over 3 years, in samples taken from the top 15cm of soil.

Quantity of CO_2 sequestered (t) by a total soil carbon increase of 0.15%, to 0-15cm soil depth and bulk density 1.5g/cm^3 over an area (ha) in one year.

Table 1.

Agricultural area to be treated (ha)	Area as a % of the Total Cropped Area in Australia (dryland & irrigated)	Equivalent CO_2 sequestered (tonnes)	% of Australian annual CO_2 emissions	Value of carbon credits to farmers
1		12.39		
200 000	0.8	2 478 000	0.41	$37.17 M
4 940 000	20	61 206 600	10.2	$918.1 M
12 350 000	50	153 016 500	25.5	$2.3 B

The conservative estimate is that 25% of Australia's annual CO_2 emissions can be sequestered by 50% of Australia's cropping land adopting biological farming systems and increasing soil carbon.

Table 1 Assumptions:

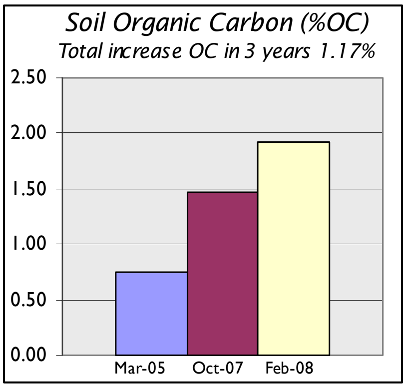
1. Soil carbon content is usually expressed as a concentration (%). To convert from concentration to stock (t/ha) the depth of measurement and soil bulk density parameters are required. Standard soil sampling methods used in agriculture are to a depth of 15cm, however sampling to greater depths is recommended for future assessment. Soil bulk density (g/cm^3) is the dry weight (g) of one cubic centimetre (cm^3) of soil and varies with different soils and depths. Most soils range from 1.0-1.8 g/cm^3. An average bulk density of 1.5 g/cm^3 is assumed for the calculations. The soil carbon stock is determined by multiplying the carbon concentration (%) by the bulk density (BD) by the soil volume in a 15cm profile of a one hectare area.
2. Carbon dioxide equivalent sequestered will be calculated by multiplying the carbon stock by 3.67. Every one tonne increase in soil carbon represents 3.67 tonnes of carbon dioxide sequestered from the atmosphere.
3. Soil carbon increase is a conservative 0.15% per annum. BFS field results have shown soil carbon to increase by 1.2% over 3 years (0.4% per annum), in samples taken from the top 15cm of soil.
4. Australian CO_2 emissions currently total 600M tonnes per annum
5. Carbon credits are valued at $15 per tonne of CO_2 for calculations

Biological Farming Systems Field Example

LawrieCo have established a precedent of outstanding increases in soil fertility with biological farming systems. On farm results indicate a high potential for Australian agriculture to sequester significant atmospheric carbon dioxide and reduce fertiliser use with subsequent reductions in nitrous oxide emissions. Charts showing increases in soil carbon and reductions in fertiliser use are displayed below.

'Kriegfields'

- Broad acre continuous cropping, Mid North South Australia
- Started using BFS in 2005, yields have maintained or improved and reduced pest and disease
- 0.7-1.2% trend increase in soil organic carbon in 3yrs
- Reduced fertiliser use by 70% phosphorus and 85% nitrogen compared to previous use



Fertiliser Use Compared	Phosphorus Units or kg	Nitrogen Units or kg	N_2O Emissions (kg) Over 400Ha	CO_2 Equivalent (kg) Over 400Ha
80-100kg/Ha DAP 6okg/Ha UREA **(2005) Pre BFS TOTALS**	**18**	**44.2**	221	68,510
30-50kg/Ha 15:13:0:9 Growth foliar 2-3 L/Ha (x2 app) **(2008) BFS TOTALS**	**5.4**	**6.25**	31.25	9,687.5
Fertiliser reduction/ Potential Emissions Saved	**12.6/Ha (70%)**	**37.95/Ha (86%)**	**189.75**	**58,822.5**

*Assumptions: (*Source: Nitrous oxide emissions from cropping systems. 16.01.07 GRDC Research Update)

1. 1.25% of all inorganic nitrogen fertiliser is emitted as N_2O
2. N_2O has 310 times more global warning potential than carbon dioxide

Arie Nieuwenhuizen

Princetown Vic

Pasture/ Dairy with 240 milkers

900mm average annual rainfall

150Ha

Unsolved Issues & Rationale to Change

- Purchased property 8 years ago
- Heavy hard clay, minimal top soil in some paddocks
- Run down with heavy chemical fertiliser use for previous 30 years
- At the time some paddocks were black with crickets (very detrimental to grass growth and roots)
- Pasture growth had no response to chemical fertiliser applications in early stages
- Aim to improve herd health through better quality pasture, reduce supplementary feeding, improve soil fertility for higher quality pasture which stays greener longer, build top soil

The Transition to BFS/ Natural Farming

- Moved to natural farming principles 6-7 years ago
- Early soil tests indicated low calcium to magnesium ratio (4.9), low soil biology – addressed with lime applications, fish compost, trace elements – saw slow improvement in pasture performance

2008/09

- Organic Matter 4.8%
- Soil tests showed improved calcium to magnesium ratio (5.37)
- Applied BioLogic blend 650kg/ha in October 2008
- 4 complete nutrition foliars (including fulvic) – 2 autumn, 2 spring
- After autumn rain, water infiltration was improved (less runoff) and pasture response faster with better coverage (following dry summer)
- After significant winter rain, soil recovers quicker (reduced water logging)
- Good worm activity
- Herd health improved – less ryegrass staggers, lice is hardly visible, cell count in milk reasonable
- Reduced cricket issue through building soil structure and reducing cracking in the summer
- Slowly improving pasture mix with new clover species appearing
- Clumps of manure are broken down more quickly in pasture (soil biology) – more even grazing

Chris Huffadine

Melrose Rd, Cooriemungle Vic

Pasture/ Dairy with 320 milkers

800-1000mm average annual rainfall

153Ha

Unsolved Issues & Rationale to Change

- Cut down nitrate fertiliser use.
- Cracks in soil with cricket infestations.
- Seeking fertility improvement.
- Anaerobic patches with cape weed and black nightshade weeds.
- Desire to be carbon neutral and a deep 'shade of green'.

The Transition to BFS

- Animal methane decrease
- Cows a lot calmer.
- Pasture now being grazed more evenly.
- Production maintained.
- **SOC level current average of 3.78 across the property**
- Reduction in nitrogen fertiliser use (see Chart 3)
  - Prior to BFS, was using 4 sprays per year of urea + Blended NPK fertiliser.
  - **Reduced nitrogen input by 86% on foliar-late season fertiliser applications alone.**
  - **Giving a potential reduction in N_2O emissions of over 300 kg/year for the property. In terms of CO_2 equivalent, the Huffadines have potentially reduced emissions by 93.9T** (see chart 3 below).

Nitrous oxide (N_2O) is a greenhouse gas that can be emitted from agricultural soils. N_2O is of particular concern as it has 310 times more global warming potential than carbon dioxide (CO2) and contributes to the destruction of the ozone layer.
Overseas research suggests that 1.25% of all inorganic nitrogen fertiliser is emitted as N_2O from cropped soils.

In Australia almost 90% of the increase in N_2O emissions (from 1990-1999) has been attributed to an increase in the rate of N fertiliser use. The main strategies proposed to minimise N_2O emissions from agricultural soils are to improve the efficiency of nitrogen fertiliser use and to minimise the incidence of waterlogging.

Source: Nitrous oxide emissions from cropping systems. 16.01.07 GRDC Research Updates

Chart 3. **Comparison of nitrogen fertiliser use Pre and with BFS**

	Nitrogen Input Units or kg	**N_2O Emissions** (kg) Over 153Ha	**CO_2 Equiv.** (kg) Over 153Ha
Pre BFS			
UREA 100kg/Ha (4 X per year)	184/Ha		
TOTAL	**184/Ha**	351.9	109,089
BFS foliar program			
Growth N 20 L/ha (4 applications)	25.6/Ha		
TOTAL	**25.6/Ha**	48.96	15, 177.6
Reduction in N / Potential Emissions Saved	**158.4/Ha (86%)**	302.94	93,911.4

Assumptions made in these calculations:

- 1.25% of all inorganic nitrogen fertiliser is emitted as N_2O
- N_2O has 310 times more global warning potential than carbon dioxide

EG. If over 300 dairy properties (av. 150 ha) in the Western District of Vic also applied 4 x 100Kg/Ha Urea per year. The emissions saved pa potentially is 90.9T N_2O, equivalent to 28,170T of CO_2 pa.

Brian Wilson ‘Briandra’

Bradshaws Rd, Mingay VIC

Mixed farming: Sheep and Predominantly Cropping

650mm average rainfall

1070Ha

Brian is a pioneer in Raised Bed methods, Southern Farming Systems Research and Landcare evaluation of BFS

Unsolved Issues & Rationale to Change - 2005

- Increasing cost and volume of chemical fertiliser needed to get the same results.
- Soil becoming compacted.
- Increasing pest and diseases.
- Lime applications of up to 7 t/ha improved Calcium : Magnesium Ratios only marginally
- Management of stubbles was the key motivation for initially looking at new solutions. Crop disease from Alleopathic negative effect from previous years’ stubble on subsequent crop was a major problem. Burning was adopted for 2 years, but also considered unsustainable.

The Transition to BFS

- 2004/5 Initiated trial work conducted by DPI to evaluate BFS Stubble Digestion Program. Protocol was ‘Nearest neighbour Design’. Canola was sown into previous wheat crop which had yielded 5.4 t/ha. Canola yield on BFS treatment was 75% higher than the mean average of other plots [2 low yield plots were not included in average due to bird damage to seedlings in trial]
- From 2005 BFS has increasingly been adopted, with rotational applications of Biologic blend for conditioning soil at 375kg/ha.
    - Some paddocks, now considered to be best performing have had up to 1 t/ha blend.
    - Since then Calcium to Magnesium Ratios have progressed from 2:1 towards 5:1.
    - Corresponding available phosphorous has moved 50% with over 100% increase in some paddocks.
    - Olsen P levels up to 19ppm had not been achievable previously on these soils.
- Fertiliser inputs have progressively reduced from typical 150 kg/ha of MAP prior to 2005. In 2008 60 kg/ha was applied. 50 kg/ha is planned for 2009.
- Soluble humate granules and VAM seed dressings used with sowing, along with digestion of all residues are now standard practice.
- Crops and pasture all now have large increases in root matter and density.
- Believes in monitoring soil physical properties more than chemical.
- Brian says “the areas where more of the program, including biologic blend have been applied, infiltration rates have increased, mineral availability and balance have improved, and insect damage and pathogenic disease have decreased.”
- In 2008 the decision was made to adopt BFS as normal practise across the whole enterprise.
- **SOC has increased significantly in pasture and maintained at satisfactory levels in cropping (Table 4 on next page).**
- Yields are very favourable compared to district benchmarks.

Table 4. **History of SOM, SOC and TEC Figures for Paddocks: Cottage South, Weir South and Haystack**

Sample Name	Date	Colloidal Organic Matter	Soil Organic Carbon (OM/1.72)	Total Exchange Capacity (TEC)
Cottage South	22/02/2005	3.8	2.21	20.43
Cottage South	5/10/2006	6.6	3.84	20
Cottage South	17/10/2008	5.4	3.14	21.45
Weir South	22/02/2005	3.5	2.03	19.64
Weir South	14/09/2007	3.7	2.15	22.25
Haystack Biology	5/10/2006	5.7	3.31	20.9
Haystack Biology	17/10/2008	5.2	3.02	23.84
Haystack Conventional	5/10/2006	5.2	3.02	23.54
Haystack Conventional	14/09/2007	5.1	2.97	22.72

Cottage South is pasture.
Weir South is rotationally cropped: 05 beans, 06 wheat, 07 canola, 08 barley
Haystack is rotationally cropped: 05 wheat, 06 field peas, 07 barley, 08 canola

2005 - Management of stubbles was the key motivation for initially looking at new solutions such as BFS. The negative effect of crop disease on subsequent crops was a major problem. Burning was adopted for 2 years, but also considered unsustainable.

John and Caroline Buchholz

Skipton Rd, Lismore Vic

Mixed farming

550mm average annual rainfall

445 Ha

Unsolved Issues & Rationale to Change

- Soil degradation.
- Lack of improvement. If anything, going backwards.
- Applications of lime and gypsum had not improved friability of heavy soils.
- Desire to reduce chemical use for health and family reasons.
- Difficult to make a quid.

The Transition to BFS

- Stabilisation of soils with no backward tendencies.
- Stubble digest fungi* used on some crops this year with obvious differences in breakdown.
  - Stubble no longer burnt which was common practice previously.
- Decreased requirement for insecticide use.
  - Use Fulvic acid to minimise volume required.
  - Ensuring correct pH level of water prior to mixing has also improved efficiency.
- Improved plant Brix (sap sugar level) readings in the crops where BFS used.
- Measuring and monitoring a key to knowing what is going on in the crop.
- Changed to Liquid Inject for seeding this year after steadily decreasing DAP fertilizer over the last few years.
- Not handling as much chemical across the board which is extremely important to family.
- Farming is fun again. It's a good feeling to get up and go to work.
- **Average SOC levels of 1.72 (2006)**

Lismore Landcare Involvement

- Began in 2008 with the aim of scientifically measuring, over three years, the differences between Conventional and BioLogic Farming Systems.
- Supported by the Department of Agriculture, Fisheries and Forestry (under the National Landcare Program).
- This project is expected to complete in 2010 (three years) to properly measure any variables in the performance level of farms using BioLogic practices.

***There is a correlation between SOC and soil fungal activity[1]**

In chemically farmed agricultural soils, bacteria are generally dominant over fungi and undertake the decomposition process of dry plant matter. When bacteria break down plant matter less carbon is assimilated into their biomass when compared to fungi; in some cases the fungal storage of carbon was 26 times greater than the corresponding bacterial storage of carbon[1]. During the bacterial breakdown of organic matter more carbon is lost to the atmosphere - an inefficiency of the carbon cycle in chemical agricultural systems.

Fungi are generally much more efficient at assimilating and storing nutrients than bacteria. One reason for the higher carbon storage by fungi lies in the chemical composition of their cell walls. They are composed of polymers of chitin and melanin, making them very resistant to degradation. Bacterial membranes, in comparison, are phospholipids, which are energy-rich and they degrade easily and quickly while functioning as a food source for a wide range of microorganisms.[1]

1. Bailey VL, Smith JL, Bolton H Jr, (2002), Fungal-to-bacterial ratios in soils investigated for enhanced C sequestration, Soil Biology & Biochemistry, 34, 997-1007

Nick & Jeff Ottens 'Tarama'

Lochiel SA

Broadacre continuous cropping

300-320mm average annual rainfall on plains

(Rainfall is higher in hills country)

1200Ha

First crop using LawrieCo BFS in 2008

Unsolved Issues & Rationale to Change

- Reduce inputs
  - High early inputs wasted if season turns dry
  - No retention of unused nutrients for the following season.
- Improve soil health
- Use available moisture more effectively
- Maintain grain quality in season's with a dry finish

The Transition to BFS

- 2 worst paddocks chosen for the BFS:
  - P1 Hard setting red clay with poor water infiltration and poor water holding capacity
  - P2 Salinity and compaction problems
- Having followed the BFS Seeding Program which had reduced upfront input costs, Jeff commented "I have never seen crops so even and healthy, just after emergence on the farm."
- P2 Sodic was treated with humates and seed dressing (SCV). Outcome was improved yield, exceptional brix readings and increased disease resistance. Still some bare patches which will be addressed this year with BioLogic Blend application.
- Foliar sprays were applied at 6 weeks after emergence and just prior to head emergence.
- No disease or insect attack concerns in the BioLogical crops as the Brix* readings ranged from 18 to 22 and Sap pH from 6.3 to 6.4.
- Prior to BFS introduction, changed to using manure for fertilising had occurred. However with BFS focus on adding biology, humates and mycorrizial fungi in the system, they are now seeing cumulative results in improved soil fertility, yield and quality.
- Precision fertilising with BFS is a real risk reduction. Had the season dried off early, second foliar would not have been applied.
- **Currently average property levels are 1.6 for SOC and 32.19 for TEC.**

Crop on sodic soil with Brix 22 and sap pH 6.4

***The Link: Brix and Insects**

During a crop inspection Nick observed some Red Legged Earth Mite in the crop. A closer investigation revealed that the RLEM was attacking the ryegrass in the crop.

Brix readings on the ryegrass were only 6 while the crop had a reading of 18; the ryegrass was weaker due to changing soil conditions not favouring ryegrass at all.

Brian & Stephanie Krieg
'Kriegfields'

Shadwells Gap Rd, Snowtown SA

Broad acre cropping

410mm average annual rainfall

400Ha, + lease & share farming

Unsolved Issues & Rationale to Change

- Concern over the increasing fertiliser and chemical inputs without replacing trace elements, and the increasing cost of chemical inputs.
- Desire to increase water and nutrient holding capacity of the soil, especially to buffer the effects of seasons with dry finishes
- Concern over undesirable screening results

The Transition to BFS

- Since 2005, annual or biennial tests taken to monitor nutrient requirements with the following results:
  - In 2008, 14 Tissue Tests were taken and NONE were Nitrogen Deficient despite cutting out pre-seeding and foliar dressing applications of Urea.
  - **Paddocks have shown increases in soil organic carbon, up to 1.17% since 2005.** See Chart 2 over page. Next tests due in October 2009.
- **Significant reduction in fertilizer**
  - **With 5 years under BFS, the Krieg's are now applying 15% of the Nitrogen previously used.**
  - **Equates to reduced potential N_20 emissions of 189 kg/year for the property (400ha). In terms of CO_2 equivalent; the Krieg's have potentially reduced their emissions by 58.8T pa** (see chart 1).
- Reduced disease issues have been an added bonus of using BFS.
  - No fungicide applications for the past three years on bean crops which had previously been sprayed two to three times per season with fungicide.
  - Reduced stripe rust pressure in wheat in low and high risk seasons
- The change to BFS has been achieved with no loss of yield productivity.

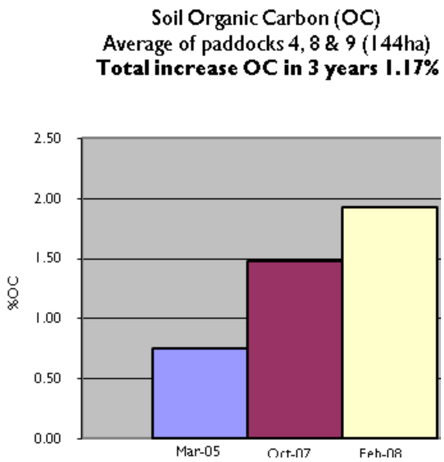
Chart 1: **Comparison of fertiliser use Pre BFS and with Biologic Farming Systems**

Fertiliser	**Phosphorus** Units or kg	**Nitrogen** Units or kg	**N_2O Emissions** (kg) Over 400Ha	**CO_2 Equiv.** (kg) Over 400Ha
Pre BFS (pre 2005)				
80-100kg/Ha DAP	16-20/Ha	14.4 – 18/Ha		
60kg/Ha UREA		27.6/Ha		
Pre BFS TOTAL (average of above)	**18/Ha**	**44.2/Ha**	221	68,510
BFS (post 2005)				
30-50kg/Ha 15:13:0:9	3.9 - 6.5/Ha	4.5 - 7.5/Ha		
Foliar spray Growth 2-3 L/Ha (x2 app)	0.14 - .21/Ha	0.2 - 0.3/Ha		
BFS TOTAL	**5.4/Ha**	**6.25/Ha**	31.25	9,687.5
Fertiliser reduction/ Potential Emissions Saved	**12.6/Ha (70%)**	**37.95/Ha (86%)**	**189.75**	**58,822.5**

*Assumptions made in these calculations: (*Source: Nitrous oxide emissions from cropping systems. 16.01.07 GRDC Research Updates)

- 1.25% of all inorganic nitrogen fertiliser is emitted as N_2O
- N_2O has 310 times more global warming potential than carbon dioxide

Chart 2: **SOC Trend on Paddocks at Kriegfields**



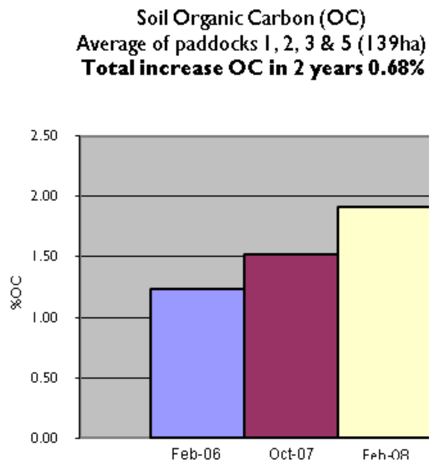


Chart Notes:
Random samples taken from top 15cm of soil
Same laboratory used for all tests

Advantage of SOC & Water Holding Capacity

- SOC provides the best means to store water inside the "root zone" of the soil.
- Quality carbon sources added by BFS:
  - Stimulated biology
  - Use of high quality humates and humus inputs
  - Clever decomposition of stubbles
  - Increasing the number of active, fibrous plant roots
- **Research shows that, on average, one part soil humus can retain four parts of soil water. Thus a 1% increase in SOC results in an ADDITIONAL 14mm of rainfall per square metre held in the soils top 30cm.**
- GRDC's water use efficiency (WUE) example shows that improving soil water storage by only 5% (22mm) increases gross margin by 21% through potential increases in crop yield (GRDC "Rain to Grain" 2007).

Evidence of fungal activity down to 200mm depth during soil physical examination – June 2008

Australian Perry Agricultural Laboratory

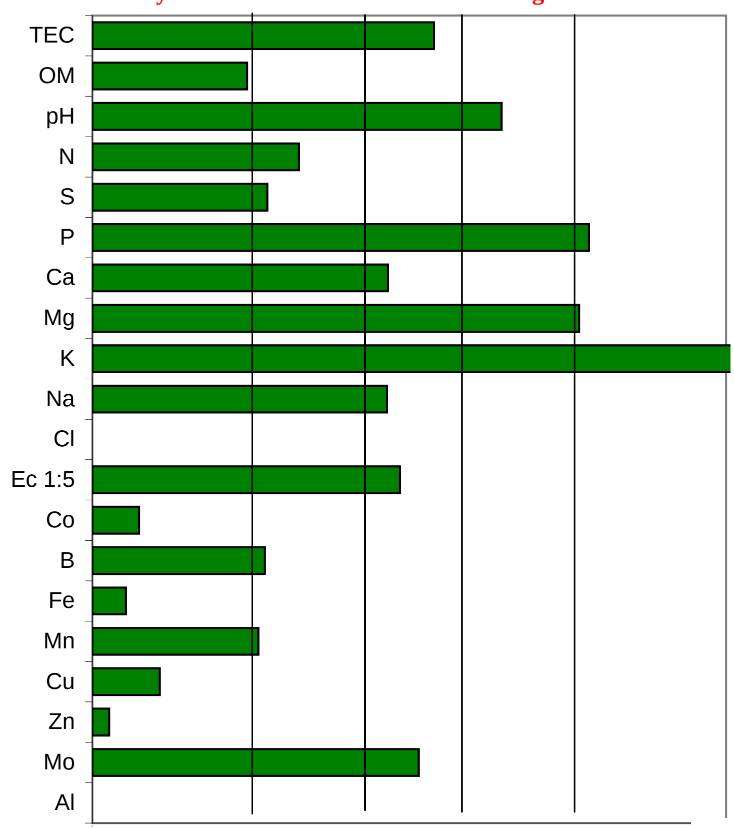
Control 10623

Customer: BRIAN KRIEG	**Advisor:**		
Sample Name: NO. 3	**Crop:** BEANS		
Lab No.: E0008	**Date:** 13-Feb-06		

LawrieCo Biological Farming

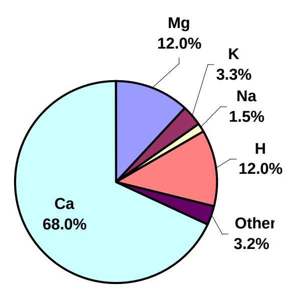
	Unit	Desired Level	Level Found
Total Exchange Capacity (TEC)		12-25	21.88
Colloidal Organic Matter %		4.0 - 6.0	2.30
PH (Water)		6.0 - 6.5	7.30
Anions			
Nitrogen (N)	kg/ha	90 - 120	69
NO 3	ppm		217.8
NH 3	ppm		4.8
Sulphate (S)	ppm	20 - 30	13
Olsen (P)	ppm	18-28	pH<7.5
Phosphorus (Bray 2)	kg/ha	127	152
Deficit	*kg/ha*	*Units P*	0
Phosphate Recovery	%	100	56
Cations		ppm	kg/ha
Calcium (Ca)	Desired	2974	6683
	Found	2933	6592
	Deficit		91
Magnesium (Mg)	Desired	315	708
	Found	490	1100
	Deficit		0
Potassium (K)	Desired	281	632
	Found	700	1572
	Deficit		0
Sodium(Na)	*Found*	98	220
Chlorides (Cl)	ppm	<250	*
Salinity EC 1:5	dS/m	<0.15	0.23
Trace Elements			
Cobalt (Co)	ppm	>1.5	0.26
Boron (B)	ppm	>0.8	0.96
Iron (Fe)	ppm	100 - 400	10.00
Manganese (Mn)	ppm	80 - 140	37.00
Copper (Cu)	ppm	>2.0	0.50
Zinc (Zn)	ppm	>8.0	0.50
Molybdenum (Mo)	ppm	0.8 - 2.0	1.52
Aluminium (Al)	ppm	<2.0	*
Base Saturation %			
Ca:Mg RATIO		5.67	3.59
Calcium	% Ca	68.0	67.1
Magnesium	% Mg	12.0	18.7
Potassium	% K	3.3	8.2
Sodium	% Na	1.5	2.0
Other Bases	%	3.2	4.0
Exchangeable Hydrogen	% H	12.0	0.0

* This test is available but not requested by client.



Base Saturation Percentages

Desired



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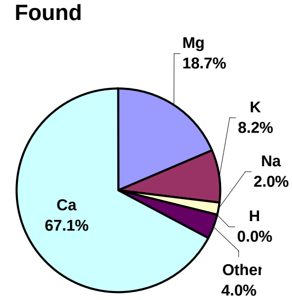


Additional Comments:

APAL, PO Box 327, 489 The Parade, Magill SA 5072 T. 08 8332 0199 F. 08 8361 2715

Australian Perry Agricultural Laboratory

Control 13869

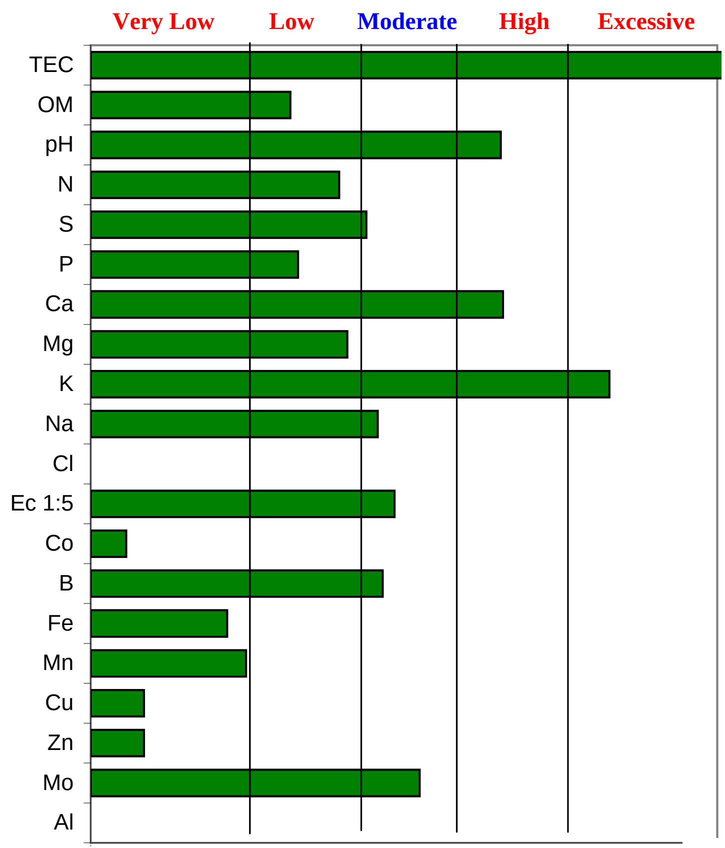
Customer: KRIEGFIELDS
Advisor:

Sample Name: NO. 3
Crop: BARLEY

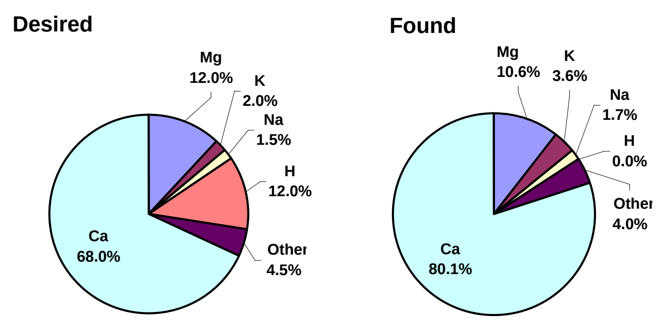
Lab No.: D0006
Date: 12-Oct-07

LawrieCo
Biological Farming

		Unit	Desired Level	Level Found
	Total Exchange Capacity (TEC)		12-25	**53.39**
	Colloidal Organic Matter %		4.0 - 6.0	**3.00**
	PH (Water)		6.0 - 6.5	**7.40**
Anions	**Nitrogen (N)**	**kg/ha**	90 - 120	**84**
	NO 3	***ppm***		**2.4**
	NH 3	***ppm***		**4.2**
	Sulphate (S)	***ppm***	20 - 30	**24**
	Phosphorus (Bray 2)	**kg/ha**	190	144
	Deficit	***kg/ha***	***Units P***	**45**
	Phosphate Recovery	**%**	100	**52**
Cations			ppm	**kg/ha**
	Calcium (Ca)	**Desired**	7257	**16308**
		Found	8545	**19203**
		Deficit		**0**
	Magnesium (Mg)	**Desired**	768	1727
		Found	680	1527
		Deficit		**200**
	Potassium (K)	**Desired**	416	**935**
		Found	749	**1684**
		Deficit		**0**
	Sodium(Na)	***Found***	210	**471**
	Chlorides (Cl)	***ppm***	<250	*****
	Salinity EC 1:5	**dS/m**	<0.15	**0.23**
Trace Elements	**Cobalt (Co)**	***ppm***	>1.5	**0.20**
	Boron (B)	***ppm***	>0.8	**1.91**
	Iron (Fe)	***ppm***	100 - 400	**41.00**
	Manganese (Mn)	***ppm***	80 - 140	**35.00**
	Copper (Cu)	***ppm***	>2.0	**0.40**
	Zinc (Zn)	***ppm***	>8.0	**1.60**
	Molybdenum (Mo)	***ppm***	0.8 - 2.0	**1.60**
	Aluminium (Al)	***ppm***	<2.0	*****
Base Saturation %	**Ca:Mg RATIO**		**5.67**	**7.56**
	Calcium	***% Ca***	**68.0**	**80.1**
	Magnesium	***% Mg***	**12.0**	**10.6**
	Potassium	***% K***	**2.0**	**3.6**
	Sodium	***% Na***	**1.5**	**1.7**
	Other Bases	***%***	**4.5**	**4.0**
	Exchangeable Hydrogen	***% H***	**12.0**	**0.0**



Base Saturation Percentages



Additional Comments:

Cobalt	*Limit of Detection*	**0.20 ppm**

Australian Perry Agricultural Laboratory

Control 14305

Customer: KRIEGFIELDS

Advisor:

Sample Name: NO. 3

Crop: FEED BARLEY

Lab No.: A0005

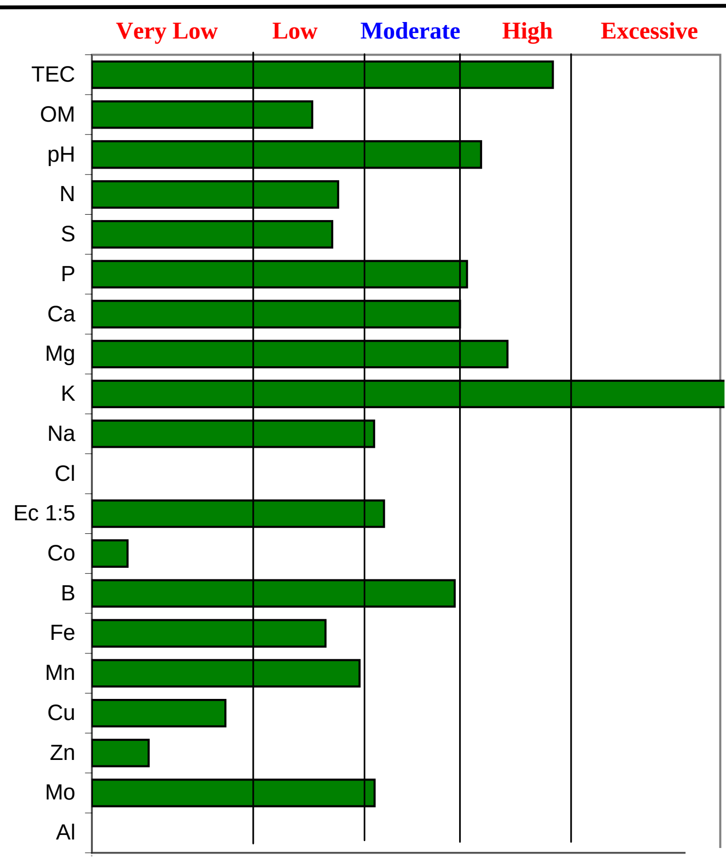
Date: 8-Feb-08

LawrieCo Biological Farming

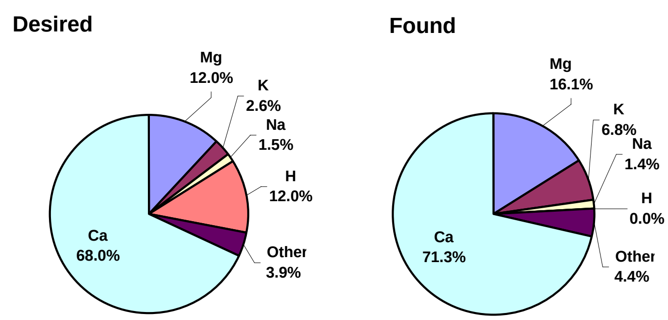
		Unit	Desired Level	Level Found
	Total Exchange Capacity (TEC)		12-25	31.90
	Colloidal Organic Matter %		4.0 - 6.0	3.30
	PH (Water)		6.0 - 6.5	7.00
Anions	Nitrogen (N)	kg/ha	90 - 120	83
	NO 3	*ppm*		20.4
	NH 3	*ppm*		7.8
	Sulphate (S)	*ppm*	20 - 30	18
	Phosphorus (Bray 2)	kg/ha	144	196
	Deficit	*kg/ha*	*Units P*	0
	Phosphate Recovery	%	100	56

Cations			ppm	kg/ha
	Calcium (Ca)	Desired	4336	9744
		Found	4547	10219
		Deficit		0
	Magnesium (Mg)	Desired	459	1032
		Found	615	1381
		Deficit		0
	Potassium (K)	Desired	323	727
		Found	850	1909
		Deficit		0
	Sodium(Na)	*Found*	101	226

		Unit	Desired Level	Level Found
	Chlorides (Cl)	*ppm*	<250	*
	Salinity EC 1:5	dS/m	<0.15	0.17
Trace Elements	Cobalt (Co)	*ppm*	>1.5	0.20
	Boron (B)	*ppm*	>0.8	2.51
	Iron (Fe)	*ppm*	100 - 400	70.00
	Manganese (Mn)	*ppm*	80 - 140	61.00
	Copper (Cu)	*ppm*	>2.0	1.00
	Zinc (Zn)	*ppm*	>8.0	1.70
	Molybdenum (Mo)	*ppm*	0.8 - 2.0	1.00
	Aluminium (Al)	*ppm*	<2.0	*
Base Saturation %	Ca:Mg RATIO		5.67	4.43
	Calcium	*% Ca*	68.0	71.3
	Magnesium	*% Mg*	12.0	16.1
	Potassium	*% K*	2.6	6.8
	Sodium	*% Na*	1.5	1.4
	Other Bases	*%*	3.9	4.4
	Exchangeable Hydrogen	*% H*	12.0	0.0



Base Saturation Percentages



Additional Comments:

Cobalt *Limit of Detection* **0.20 ppm**

Barry, Matt & Simon Vogt
'Hester Holdings', Kapunda SA

Mixed farming using No-Till farming system

500mm average annual rainfall

900Ha

Unsolved Issues & Rationale to Change

- Always interested in soils, but BFS offered a whole farm system.
- Recognised compaction / hard pan issues about 20 years ago and progressed into No-Till.
- No-Till farming, while offering improvements, was not building soil organic carbon and hence there was no significant improvement in nutrient balance.
- Expensive fungicide sprays.

The Transition to BFS

- BFS introduced with production maintained and margins improved.
- 2006 – 3% higher oil on BFS Canola with lady birds evident.
- 2007 – Dry finish and yields down. Grain was better quality on BFS patch.
- **Feb 2008 – Soil test SOC readings between 1.86% and 2.26%.**
  - Barry comments "this is the highest I have seen in a long time."

2008 Comparison

	BFS Paddock	Pair Paddock Conventional
Inputs	**30% Less Fertiliser Used at Seeding** 70 Kg/Ha DAP, Humate & SCV seed dessing No fungicides	100 kg/Ha DAP, 100 kg/Ha Urea
Output	Flagship barley 4.7 T/Ha Malt1 Gross margin $270 / Ha over conventional	4 T/Ha Malt1 + 0.7 T/Ha Screenings (Grain had to be cleaned for sale)
Rust	No signs rust. Preventative biology sprayed to maintain high Brix levels in the crop	Rust developed > controlled by spraying twice with beneficial biology
Other	Impressive organic matter and friability At least 3 earth worms in every hole dug Significantly improved water infiltration	

John Kalleske ‘Kalleske Enterprises’

St Johns Rd, Greenock SA

Vineyard, Pasture, Cropping, Organic Wiltshire lambs and Commercial chaff mill

520mm average annual rainfall

200Ha

“Wine Quality Starts in the Soil”

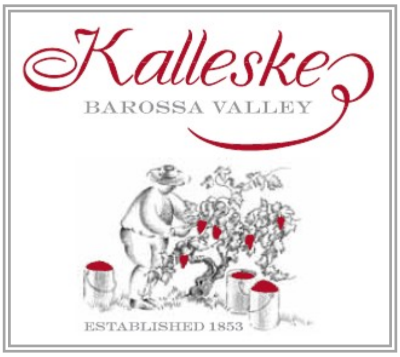
Unsolved Issues & Rationale to Change

- Always tended toward natural production methods.
- Do not agree with increasing use of chemical fertilisers.
- Quality was the objective.
- Compaction in hard soils.

The Transition to BFS/ Organic/ Biodynamic

- Significant difference in soil structure compared to conventional > greater friability and water infiltration.
- Ideal Calcium to Magnesium and other mineral ratio’s.
- Improved soil fertility and management allowing for low input system.
- Active practitioners of sustainable farming.
- Caretakers of the land and not only want to maintain the environment, but improve it for future generations.
- The vineyard is low yielding, with grapes grown with BFS principles, organically and biodynamically.
- Several winemakers over the past 8 years, now including our son Troy, advise us that the grapes we deliver have a good natural balance of minerals. They have noticed that this makes their work to produce premium wine much easier.
- The Kalleske’s seek to deliver mineral balanced and high quality produce from their farm.

Kalleske Wines - Troy and Tony Kalleske



The Kalleske family have been farming and growing grapes since 1853 near Greenock. They are one of the regions leading grape-growing families, consistently growing some of the Barossa's best quality grapes. After six generations of growing grapes, winemaker and seventh generation family member, Troy Kalleske, together with his brother Tony, established the Kalleske winery and made the first ‘Kalleske’ wine.

The 120 acre vineyard is planted to Shiraz, Grenache, Cabernet Sauvignon, Semillon, Chenin Blanc, Mataro, Petit Verdot, Durif, Viognier, Tempranillo and Zinfandel. All Kalleske wines are estate grown and vinified with minimalist winemaking techniques to fully capture the essence of the vineyard, allowing genuine hand made estate wines to be produced. The range is a diverse mix of wines that showcases the splendid Kalleske grapes.

Since the first wine release in 2004, Kalleske has rapidly gained a reputation for producing top-quality, hand crafted wines.

Wines from Kalleske have been seven generations in the making, but they are certainly worth the wait!

Recent Awards

- Kalleske – 5 star winery – outstanding winery - James Halliday
- Troy Kalleske – Barossa Winemaker of the Year 2008
- Troy Kalleske – Australia’s Young Gun of Wine – V-know Young Gun of Wine Awards 2007
- Trophy & Blue Gold Award – Sydney International Wine Competition 2008
- Trophy for Best Wine of Show and Best Red Wine of Show — Australia/NZ Organic Wine Show 2007

Darryn Smith

Guys Rd, Cooriemungle VIC

250 head jersey dairy

750mm average annual rainfall

70 Ha

Unsolved Issues & Rationale to Change

- Build better soil and then better pasture will come from that.
- Maintain and improve productivity through the transition.
- Preserve Ryegrass with improved stem tillering and deeper root mass.
- Encourage improved herbage mix of the pasture.
- Make the BioLogic changes happen within the season rather than over extended seasons.

The Transition to BFS

- "The results I saw after the first two months matched the outcomes that I thought would take three or four years," Darryn comments.
- Extra root growth is a key feature since implementing BFS, contributing to improved soil friability with better moisture infiltration. Darryn comments, "Previously each plant basically had one main root and the soil was solid and hard to crack with a hard pan five centimetres below the surface."
- Return of dung beetles after three years.
  - Increased root penetration and soil aeration resulting in more friable soil.
  - Increased water penetration
  - Fly breeding sites removed.
  - Nutrients locked in dung released into soil, reducing need for fertiliser.
  - Reduced polluted runoff
  - Increased pasture productivity
- Reduced vet requirements: From 1-2 visits per week to once a month in the four months since November, with recent additional veterinary care required during calving.
- Summer feed supplements not required
- Pasture is staying greener longer, producing higher quality grasses with increased sugar levels. Of particular note is the return of clovers into the herbage mix
- Cows are also grazing the pasture much lower than before.
- Stock lick blocks are making sure there's better rumen efficiency and feed utilisation until the soil and pasture cycle is perfected.
- **SOC in spring 2008 was 2.06, with a TEC of 25.14.**

Peter Gannon

Murroon Rd, Murroon Vic

Mixed farming: 50% ryegrass seed production & 50% prime lamb/beef

800mm average rainfall
(500-600mm av for last 5 years)

500Ha + 100Ha leased

Unsolved Issues & Rationale to Change

- Declining crop yields despite high applications of chemical fertiliser.
- Weed resistance to chemical sprays.
- Compacted, unhealthy soils.
- Desire to lift health of soil, improve pH and increase plant Brix levels.
- Lack of sustainability and soil fertility meant could not continue without changing farming methods.
- Concern about health of stock in general, particularly reliance on drenches.

The Transition to BFS

- 2008 – half cropping area used BFS, focusing on BioLogic Blend, microbes and some foliar Growth and Fruiting sprays, but no Urea or DAP. The other half of the property was farmed conventionally with 100kg DAP and 100Kg Urea in September and October.
  - ➢ No yield loss on BFS paddock despite replacing all urea applications with 2-3 foliar sprays.
- Initially resistant to brewing microbes on-farm due to time and technical details.
  - ➢ Actually found them easy to implement and got into a pattern
  - ➢ Brewing on-farm gives flexibility to brew and apply when conditions are most appropriate and to fit with the schedule.
- Where stubble digest program was applied to the crop:
  - ➢ There are better humus levels in the ground with increased soil friability.
  - ➢ Dramatic increase in the number of worms throughout the stubble.
  - ➢ Also extremely happy as the stubble broke down really well, good for seeding the next crop
- Spread Biologic Blend on the grazing paddocks to introduce biology and optimise soil conditions to increase existing biology.
  - ➢ Plant Brix and sap pH readings were higher on the BFS paddock than the conventional.
  - ➢ Results so good that this year all grazing paddocks will have BFS and no super/potash.
- **SOC levels averaged 4.1 across the property in 2007.**

Charlie Thomas

Lukies Rd, Naring Vic

Hay production & Crossbred lambs

425mm average annual rainfall with flood irrigation

400Ha

Unsolved Issues & Rationale to Change

- Looking to move away from chemicals.
- Disappearance of soil biology especially earth worms.
- Healthy soil smell remembered from ploughing 40 years ago just wasn't there anymore.
- Rock hard soils.
- Lack of water drainage/infiltration resulting in soil "glugginess" during wet years.
- Tried different organic inputs for a number of years but hadn't seen the expected results. Doing bits and pieces, but not able to find a complete farming system until BFS.

The Transition to BFS

- 2006 – attended Dr Arden Anderson seminar.
  - Started using refractometer to measure plant Brix levels.
  - Set up a microbe brewing pump and tank.
- 2006 - Following first Foliar application on Subterranean Clover, saw results within a few days.
  - Brix levels rose from an average of about 3 or 4 up to 10.
  - Colour was a brighter green.
- 2006 - Sub Clover yielded similar to that of a normal year, averaging about 6T/Ha.
  - Turned out to be a significant weight gain, because while other crops in the district looked good, the bulk wasn't there, and most were about half of average.
- **SOC level was 0.98 in 2006 and 1.39 in 2008 across the property.**
- Brix levels have increased in crops resulting in high quality hay.
- Crop retains moisture longer after cutting.
- Very few pea mite or lucerne flea problems.
  - When detected, they are controlled with Molafos and sugar.
  - No insecticide used on the farm in the last 12 months.
- Good healthy growth where irrigated with humates, compared with no growth where bore water used without humates. Humates buffering the salt (1300ppm), high magnesium and high iron levels present in the bore water allowing good plant growth.
- Earth worms now thickly populate the property again.
- Soil friability and water penetration has increased dramatically.
- No drop in yield despite significant water cuts due to the extreme drought conditions. Managed via increased water holding capacity of the soil and adapting plantings.
- Have not drenched for Fluke for the last 2 years. Fluke risk area and previously drenched 2-3 times/ year.

Peter & David Bufton ‘Staughton Vale’

Balliang, Vic

Mixed farming, mainly cropping

550mm average annual rainfall

(much less in recent years)

480Ha

Unsolved Issues & Rationale to Change

- Needing a better system.
- Concerns regarding nutrient balance in soils and quality and health benefits of food produced.
- Observing over lifetime, a progressive decline in ‘visual’ indicators of soil life activity.

The Transition to BFS

- In 2000, initiated using some BFS inputs. 2004 progressed to BFS (in its form at that time)
- Until 2004 used 90-100 DAP at seeding. 80 kg/ha Urea applied post seeding. Lime applied at 400kg/ha prior to sowing canola crops.
- BFS programs from 2004 to current (majority of paddocks):
  1. Stubbles are digested, except following severe drought.
  2. Seeding 40-50 kg/ha DAP/SOA, 5kg Soluble Humate Granules, VAM Seed Dressing.
  3. Post seeding (approx 4-5 weeks) a foliar spray of nutrients, fulvic and biology is applied.
  4. Seasonally adjusted (depending on rainfall), a second foliar may be applied.
  5. Soil amendment program with prescription Biologic Blend has commenced. Will be continued on a rotational basis around the farm, subject to drought & budget situation.
  6. 2009 Introducing Biological Liquid Inject alternative versus solid fertiliser, for evaluation.
- Soil mineral balance is progressively improving. The low nutrient levels are higher, and the excesses are coming down closer to desirable.
- Greatest impact – total elimination of, use of/need for, fungicides and pesticides. Improved soil and crop nutrition is the primary method, together with foliar biological management.
- Ryegrass (weed competing in crop) is dramatically reduced – this outcome is a significant benefit. The reduced ryegrass was an outcome in the first year following biologic blend application and has sustained for three years to date. Our crops are now stronger relative to ryegrass competition, following the BFS soil amendment program.
- Soil over all of the property is softer and does not pack down. There is much greater plant root growth and decaying mass following a crop.
- Earth worms have returned.
- Yields achieved have been comparable to other crops in the district, which is very encouraging.
- Crops with BFS tolerate tight, dry springs with less stress than our previous methods.

Summary from the Bufton’s

Biological Farming Systems have enabled hope to return in our farming vision. Previously we were seriously concerned for our future viability. We still are, however our current path has more positive components towards Soil Stewardship.

In the context of the droughts we are experiencing and our intent to leave the farm better than when we started, this advantage is critical.

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Websites

- CSIRO Website www.csiro.au
- Jones, Dr Christine, Amazing Carbon Website www.amazingcarbon.com
- Healthy Soils Australia website www.healthysoils.com.au

Bio's of Participants of the BioLogic Farming Systems Soil Carbon Tour (11-12 May, 2009)

- Listed in Alphabetical Order -

Peter Andrews, Natural Sequence Farming

Peter Andrews is a stud master, and thoroughbred horse breeder and farmer from Bylong in the Upper Hunter Valley. He is a man who many believe is way ahead of his time. Peter has gained fundamental insights to the natural functioning of the Australian landscape that leave him almost without peer. He has applied these insights in restoring his and other properties to fertility levels that he says existed upon European arrival in this country.

Over 30 years ago Peter, bought a run-down 2000 acre grazing property called Tarwyn Park, near Bylong in the Upper Hunter Valley. He then quietly set about testing the theories that he had been developing virtually ever since he was a child, growing up on a station near Broken Hill. By 1976 Peter Andrews claimed that the model he had set up on Tarwyn Park was an example of a sustainable agricultural system. Mr Andrews called his approach the Natural Farming Sequence. It has later become known as Natural Sequence Farming.

His main proposition is that our farming and land management practices over the past 150 years have systematically dehydrated the landscape. This has many adverse consequences, exacerbating the consequences of drought, reducing the productivity of land, increasing salinity, reducing moisture content within the system and thus reducing rainfall.

Peter's work is focussed on reversing the bad practices by adopting approaches learned from nature, with the objective of rehydrating the local, regional and national landscape.

Jeremy Barlow, Investor

Jeremy is a mining engineer by profession and after over 40 years in the resources industry now an active private investor. He is also a non-executive director of two public companies, namely Arrow Energy Limited (an international coal bed methane company), and Bandanna Energy Limited (a coal explorer) of which he is Chairman.

Jeremy has limited knowledge of farming but is very concerned about land degradation and the possible impact on the prosperity of future generations. So the ideas of BFS are fascinating to Jeremy, he can readily see the positive contribution that can be made by the application of BFS.

Prof. Snow Barlow, University of Melbourne

Professor of Horticulture and Viticulture

Greg Butler BSc(Hons.) GAICD, Research & Development Manager, SA No-Till Farmers Association

Greg is a life member and former president of the Adelaide University Science Association and since graduating in 1993 with honours in organic chemistry he has dedicated his efforts towards agricultural reform on a landscape scale.

Greg's real strength is his ability to identify with land managers on big picture issues early in the piece and to combine economic and practical considerations into viable technical solutions that can be adopted with confidence by farm businesses.

Greg currently manages business development and research for the South Australian No-Till Farmers Association (SANTFA), an independent not-for-profit farmer group with the largest subscribing membership of its type in Australia. Greg leads a number of collaborative projects focusing on soils, farming systems and practice change facilitation. He is a member of the World Association of Soil and Water Conservation and regularly contributes to industry publications and on-ground projects in Australia and overseas.

Greg is a graduate of the Australian Institute of Company Directors and he fulfils a non-executive directorship with the Conservation Agriculture Alliance of Australia & New Zealand (CAAANZ) and as the managing director of Agoko Pty Ltd.

His true passion to take the industry forward through genuine innovation and an increased recognition of ecosystem services has made him a highly respected contributor within the agricultural industry.

Prof. Anthony Cheshire, Principal, Science to Manage Uncertainty

Prof. Anthony Cheshire has worked for the last 25 years as an ecologist and environmental scientist including roles in private industry, government, and the higher education sector. For most of this time Anthony has worked in the Agribusiness sector primarily in association with the seafood industry.

Anthony is currently the Executive Chairman of Balance Carbon Pty Ltd a company that was established to assist industry prepare for business in a carbon constrained economy. Balance Carbon works with many industries and are currently leading a "Farming for Carbon" project on behalf of the SA Government.

Other than "Balancing Carbon" Anthony also works as an independent scientist and is the Principal of Science to Manage Uncertainty. In this role he undertakes work for both Government and Industry in developing high impact strategic R&D programs.

Anthony holds an affiliate position as Professor with the School of Earth and Environmental Sciences at the University of Adelaide and an adjunct position as Professor with the School of Biological Sciences at Flinders University.

Prof Anthony Cheshire cont.
He also holds a number of Board and Advisory positions including as a Director of the Cooperative Research Centre for Environmental Biotechnology (EB-CRC Pty Ltd), Chair of the SA Fisheries Research Advisory Board and as a Member of the SA Natural Resource Management Council.

Sandy Cornell, Lobbyist, Natural Sequence Farming
Sandy actively supports Natural Sequence Farming. Sandy is interested in land rehabilitation and restoration of natural systems in nature/ farming, also mitigation of climate change. Sandy comes from a veterinarian bakcground.

James Darling, Duck Island
James Darling's property, Duck Island, is midway between Keith and the Coorong in South Australia. He has successfully farmed Duck Island for thirty years, doubling its size while retaining over 3,000ha of native vegetation. James and his partner Lesley run 1000 cows in a composite herd targeting the EU market as well as selling composite bulls to progressive breeders. James is a combination of farmer, conservationist and artist – essential and indivisible attributes of the whole person.
He is also an activist and community leader who brings his own distinctive eloquence, common sense and passion to regional, national and international forums. In recognition for his contribution to sustainable agriculture, the environment, the arts and his community, he was awarded an AM in the Order of Australia.

Greg Donoghue, Lobbyist, Natural Sequence Farming
Greg actively supports Natural Sequence Farming. Greg is the managing director of Eco-Organics, he has a microbiology and organic farming background and strong interest in land rehabilitation.

Dr Bernard Doube, Principal, Dung Beetle Solutions Australia
Dr Bernard Doube was a Principal Research Scientist with CSIRO for 29 years and has had extensive research experience with dung beetles in South Africa and Australia. Bernard is also an international expert on earthworms and the biological basis of soil health and co-edited the books "Soil Biota: Management in Sustainable Farming Systems" (FAO-funded) and "Biological Indicators of Soil Health" (CABI-London)(second edition in preparation). Bernard is now Principal of Dung Beetle Solutions Australia, which collaborates with water authorities, federal agencies (eg MLA), universities and other organisations to research the influence of dung beetles on water quality, grazing systems and carbon sequestration in southern Australia. Dung Beetle Solutions Australia supplies starter colonies of dung beetles to producers.

Ross Fitzgerald, CEO, Spectrum Venture Management
Ross is the founding CEO of a UK-based venture capital business called Spectrum Venture Management. He is also on the Board of VISY Industries in Australia and Pratt Industries in the USA.
Formerly Ross worked as a management consultant at McKinsey based in London. Growing up in Melbourne, Ross completed an Economics Degree at Monash University and an MBA from Harvard Business School. Ross is an Australian and spends 35 per cent of his time in Australia.
Ross is passionate about the world leadership role that Australia can play in building soil carbon levels to combat climate change and increase the world's food supply. He is interested in investing in and assisting Australian companies focussed on increasing soil carbon.

Tony Grivell, Associate Professor (Retd) in the Flinders University School of Medicine, Citrus Orchard owner
Tony's tertiary training was in Agricultural Science, specialising in agricultural biochemistry, followed by a transformation to human biochemistry with a focus on clinical chemistry (and the computerisation of clinical data). Tony has had a life-long interest in ecology and sustainable human activity, most recently applied in practice in the conversion of a family citrus orchard to Organic production.

Major General Michael Jeffery, AC, AO(Mil), CVO, MC (Retd)
Major General Michael Jeffery, AC, AO(Mil), CVO, MC was born in Wiluna, Western Australia in 1937 and educated at Kent Street High School and the Royal Military College, Duntroon.
He graduated into Infantry and served operationally in Malaya, Borneo, Papua New Guinea and Vietnam, where he was awarded the Military Cross and the South Vietnamese Cross of Gallantry. After command of all combat elements of the Army from platoon to division – including the Special Air Service Regiment – he retired in 1993 to assume the appointment of Governor of Western Australia, which he held for almost seven years. His major interests during his tenure were in youth affairs, education, environment and the family.
For his services to the State he was appointed a Companion in the Order of Australia, a Commander of the Royal Victorian Order and a Citizen of Western Australia.
On his retirement as Governor in 2000 he established in Perth, a not for profit research institute – Future Directions International (FDI) – whose object is to examine longer term issues facing Australia.

Major General Michael Jeffery Cont.
On 20 December 2000 he was awarded an Honorary Doctorate of Technology by Curtin University.
On 11 August 2003 he was sworn in as the twenty-fourth Governor-General of the Commonwealth of Australia, Serving in that capacity until 5 September 2008.
Upon his retirement as Governor-General, he has accepted Chairmanship of the Royal Flying Doctor Service, FDI and Outcomes Australia, along with patronages of a number of other not-for-profit organisations.
Major General Jeffery is a Companion of the Order of Logohu (PNG), a Knight of St John, a Citizen of Western Australia, a Paul Harris Fellow and an honorary life member of the Returned and Services League.
He and his wife Marlena have four children and eight grandchildren. General Jeffery enjoys golf, cricket, fishing, reading and music.

Andrew Jones, General Manager Land/Business Development, **Australian Agricultural Company**
Andrew Jones commenced as General Manager Land with AAco in July 2006. Andrew's role encompasses management of AAco's land assets in order to maintain environmental sustainability to improve efficiency, increase productivity enhancing the value of land and fixed assets.
Having 20 years of post graduate management experience in both dry-land and irrigation operations together with a Diploma in Farm Management, Andrew has the necessary experience and skills to provide the input for this challenging role. He has relocated to Queensland from Western Australia bringing with him knowledge and experience of, the southwest environment as well as the West Kimberly northern cattle zone of Australia and some of the unique challenges these environments provide.
Andrew has previously held positions of General Manager – Farm Group, General Manager – Crop Production and Farm Operations Manager for both corporate and large scale operations throughout New South Wales and Western Australia.
Andrew has always had a strong affinity with Agriculture and enjoys the challenges this business environment offers to succeed in this rewarding Industry. The interest in the tour has been instigated by the need to better understand the role soil carbon can play in a Carbon restrained global economy and what the other benefits the Biologic Farming system can bring to modern production systems.

Louisa Kiely, B. Ag. Ec., A.Dip Farm Mgt., Director, Carbon Farming Services
Louisa obtained her Agricultural Economics degree from the University of New England. She worked in the market research industry as a field supervisor while bringing up her 3 children. In 1991- 2003 Michael and Louisa established and grew a city based Marketing agency from zero to 35 employees. In this business, she was Director and General Manager of Boomerang! Integrated Marketing & Advertising.
Intent on following her first choice of career, she studied for the Advance Diploma of Farm Management, trained in Holistic Management, and since 1998 she has been a woolgrower in the Wellington NSW district.
She was selected by the Central Western Catchment Management Authority as one of the 10 most innovative landholders in the Catchment, to be trained in farm planning and soil restoration. Through this training and contact with Dr Christine Jones she and husband Michael became convinced that soil carbon could solve many farming, environmental, and global warming problems. They founded the Carbon Coalition Against Global Warming in February 2006 to lobby for the right of Australian landholders to trade on the emissions offset market the credits they can earn by sequestering carbon in their soils. They have since travelled throughout Australia and the United States meeting scientists and farmers and spreading the word about "Carbon Farming". She organised and ran the world's first Carbon Farming Expo & Conference in Mudgee in November 2007,with delegates from every State in Australia and NZ.
She is co-founder of Carbon Farmers of Australia – a not-for-profit trading arm of the Carbon Coalition and organised two Soil C Summits between Scientists and Farmers, in Dubbo and Orange NSW.
She has developed the "CarbonCredited™" brand for wool and is currently recruiting woolgrowers into this emissions reduction program. Louisa has been recognized for her work by being chosen as runner up in the 2008 NSW Rural Woman of the Year, and is nominated for inclusion in the 2009 Who's Who of Australian Women for outstanding contribution to agriculture.

Michael Kiely, BA (Hons), A. Dip. A., Dip DM, Convenor, Carbon Coalition
Prior to moving to the country, Michael forged a creative career in Marketing for 30 years. He holds both the Certificate and Diploma of Direct Marketing from the Australian Direct Marketing Association (ADMA). Michael was creative director of a large agency, as well as a regular conference speaker, a lecturer and workshop facilitator for many organizations. He has been a judge for many marketing awards programs. Michael was editor of Marketing magazine for 10 years and is now executive editor. He was founding chairman and managing director of Boomerang Integrated Marketing and Advertising. He was inducted into the Australian Direct Marketing Hall of Fame in 2001.

Michael Kiely Cont.
Having moved to the country, and realising the huge challenges Agriculture faces, he set about using his skills to research all issues Concerning Farmers and Climate Change. He is now an Agriculture Climate Change Consultant and educator.
In this role Michael & Louisa are woolgrowers from the Wellington district of NSW and Convenors of the Carbon Coalition Against Global Warming, a farmers' and citizens' movement which aims to have soil carbon recognised as a major solution to Climate Change. They are also principals of Carbon Farmers of Australia a company that will aggregate and sell soil carbon credits. They have been delegates at many high level symposia in Australia and the USA. They led a fact-finding delegation to the USA on behalf of Australian farmers in 2006. While there, they negotiated the first order for soil carbon credits from the Chicago Climate Exchange. Michael recently appeared as an expert witness before the NSW Premier's Greenhouse Advisory Panel and the NSW Department of Primary Industries Climate Risk Management Project.
For the past two years, Michael and Louisa have organized and conducted the World's only Carbon Farming Conference and Expo, attracting 350 delegates from all states of Australia and also New Zealand.

Adrian Lawrie, Founder and Managing Director, LawrieCo and Farmer
LawrieCo is a leading BioLogic Farming Systems and fertiliser manufacturing company. Since the mid-late 90's Adrian has built LawrieCo up to be Australia's most successful BioLogic Farming Systems company.
The concept developed when Adrian began using (then little known) biological soil principles on his broad acre cropping property located in the marginal rainfall region between the Southern Flinders Ranges and upper Spencer Gulf region of South Australia.
Despite good yields, high inputs and use of conservation farming techniques (full stubble retention and limited cultivation) the soil was becoming more compacted, and soil organic carbon that started low, was getting lower. This trend was the catalyst for investigation of alternative farm practices and in 1996 Adrian planted 1200 hectares of crop with additional humates, soft rock phosphate and beneficial microbes brewed on site (three integral BFS inputs).
Under Adrian's guidance the company is at the forefront of Biological Sciences being translated into profitable agricultural farming systems and is now growing at an annualized rate of 30% in the conservative and conventional (but increasingly less skeptical) primary industry market.
Adrian has a lifelong passion to help farmers become more scientific, perceptive and empowered as the true stewards of their land. LawrieCo now have over 250,000 hectares across Australia under active BioLogic Farming Programs.

Tony Lovell, Director, Soil Carbon Australia
Tony Lovell is a Director and Co-founder of Soil Carbon Australia (SCA). He is a qualified Chartered Accountant in public practice as well as an active grazier.
SCA exists to raise awareness of the vital role that restoring our degraded grazing lands must play in reversing desertification, increasing bio-diversity and mitigating climate change. SCA has adopted a practical and pragmatic approach to its advocacy, and strongly believes that it will only be when a genuine commercial value is placed on the carbon content of our soils that real positive changes will begin.

Dr Graham Lyons, HarvestPlus Research Fellow, School of Agriculture, Food & Wine, Uni of Adelaide
Graham comes from a mixed farming and international agricultural development background. He specialises in micronutrients in agriculture and human health, in particular selenium, and has written several books and numerous articles. Currently manages the "HarvestPlus Food Systems" program funded by the Gates Foundation, conducting biofortification trials/programs in China, South America and Melanesia.

Andrew Michael, Owner, Leahcim Poll Merino and White Suffolk Stud
Andrew's interest in the tour comes about from Brian Krieg, his neighbour, seeing the work he is doing with his cropping and grazing sheep during the summer months on some of Brian's farm. The focus of using less chemical and balancing your soil structure sits well with Andrew's thoughts in farming. Sheep are the main source of income, they use very little chemicals but adopt all modern breeding technologies and grazing practices, the sheep have had no external chemical use for 7 years, have not been mulesed since 2004 and Andrew believes that a very good balance of pastures and cropping is a great mix for profitable farming.

Jon Miller, Managing Director, Anthro Terra P/L
Jon Miller is the Managing Director of AnthroTerra P/L. This company is conducting Research and Development to determine how best to sequester carbon into soil through agricultural applications. Prior to joining AnthroTerra, Jon has worked in the environmental sector for six years. Most recently through his own business called The Remediation Group. Previously Jon has had a diverse background spanning geodemographics, hotels, and teaching, starting with a Bachelor of Science.

Adam Morton, Environmental Reporter, The Age
Adam reports on environmental issues for The Age, focussing on climate change.

Burt Naude, Senior Field Consultant, LawrieCo
Burt completed studies in 1983 at the University of Potchefstroom majoring in Soil Science and Geology. He then farmed on a mixed enterprise property for seven years, following which he was the production manager on Big Corporate farm west of Johannesburg. In 2001 Burt and two mates from University started a Consulting Business which focussed on Precision farming and Mine rehabilitation.
Burt and his family moved to Australia in 2005 and started with LawrieCo, Burt is now a Senior Field Consultant.

Duane Norris, Natural Sequence Farming
PA to Peter Andrews

Wendy Page, Producer, Australian Story ABC
Wendy is a Reporter/Producer with Australian Story, ABC TV, Sydney. Her interest in the tour is simply as a journalist, and in particular following and filming Major General Michael Jeffery and Peter Andrews for production of a sequel to the 2005 story about Andrews.

Janine Price, Intensive Animal Industries, EPA Victoria
Janine is the Intensive Animal Industries officer working across Victoria with Feedlots (Cattle and sheep), Broiler, Egg, Piggeries, Dairy etc. She has previously worked for the Department of Primary Industries with grazing industries, effluent and nutrient management.
Janine works with a wide range of stakeholders and have an interest in farming practises which can minimise or benefit the environment whilst maintaining or improving productivity. She is also involved in industry programs, developing codes of practise, policy development and interpretation and facilitation of information between, industry, community and government.

Dr Pichu Rengasamy, Senior Research Fellow - School of Earth and Environmental Sciences, Uni of Adelaide
Qualifications: Ph.D. (Indian Agricultural Research Institute, New Delhi, 1973)
Postdoctoral experience in Belgium, Adelaide (Five years) Senior Lecturer in Soil Science in the University of Dar es Salaam, Tanzania- 2 years. Senior Research Scientist - Victorian Department of Agriculture (12 years), Senior Research Fellow- The University of Adelaide (16 years) Research.
Interest: Physical chemistry and management of saline and sodic soils
Publications: 75 journal papers; 70 conference papers; 5 chapters in books; Co-edited a book; 10 invited lectures in various international conferences.

Dr Fiona Robertson, Research (Environmental) Scientist, Future Farming Systems Research Division, DPI Vic
Fiona is a soil scientist with the DPI Future Farming Research Division, based in Hamilton, south-west Victoria. Currently she is leading a project on soil carbon sequestration, hence her interest in attending your tour.

Jean-Francois (John) Rochecouste, CEO, Conservation Agriculture Alliance of Australia & New Zealand (CAAANZ)
Jean-Francois Rochecouste has a degree in Agricultural Science majoring in Plant Pathology and a holds a Masters in Business & Environment. He has worked in field research for over 8 years for both the private sector and the Queensland Government before changing to a sales and business career with Shell Chemicals and American Cyanamid. In 1996 he worked as a principal director of MaurRoche Agriculture Pty Ltd a contract management business offering agricultural /environmental research and marketing to primary industries. He has recently taken up the position as the Chief Executive officer for the Conservation Agriculture Alliance of Australia and New Zealand. He holds a certificate IV as a Trainer and is on the technical advisory group of Queensland Chemcert. He speaks fluent French and has an interest in international framework for managing agriculture and the environment.

Russell J Rolls, Group Executive - Operations and Technical Development, Ignite Energy Resources Pty Ltd
From 2006 Russell Rolls has held the position of Group Executive, Operations and Technical Development for Ignite Energy Resources Pty Ltd. Russell has had extensive experience in the international resources industry (mining, oil & gas), having been the CEO of a number of private and publicly listed companies. As CEO, Russell developed the Clyde Industries Ltd Resources Engineering Group into an internationally recognised source of technology for the mining and process industries.
Russell is a Fellow of the Institution of Engineers, Australia and a Chartered Professional Engineer, and holds a Bachelor of Engineering (Mechanical) from Monash University, Melbourne as well as a Master of Administration (MBA) from Monash University, Melbourne.

Sean Rooney, Acting Director Business Development & Technology Earth Resources Division DPI Vic
Sean is a geologist who until recently was the Coal Development Manager for DPI. His interest is in bio-sequestration and innovative uses of lignite.

Phil Ryles, Chief Geologist, Woodside Energy
Phil Ryles is the Chief Geologist at Woodside Energy. He has 25+ years as practicing Petroleum Geoscientist covering a diverse mix of exploration through to production operations, onshore and offshore, fluvial to deep water environments. Phil specializes in petroleum exploration and development, integrated subsurface studies and opportunity evaluation, field development planning and production optimization, his primary interests are the application of new technologies to the subsurface and maintaining a "hands on" approach.
Previously Phil held positions as a senior geologist at Santos, exploration geologist with CSR Orient Oil in China and geologist at Dehli Petroleum.

Bill Saunders, CEO, Natural Sequence Farming
Bill has been interested in sustainable farming since meeting Peter Andrews a few years ago. He is currently the CEO of Peter's support group, the Natural Sequence Association and feels it is important for the NSA to be represented on this tour.
A keen horse breeder with his own stud property, Bill owns and runs the Cyberhorse web site and shares with Peter a love of thoroughbred racing.
He believes that the internet is a key tool for increasing awareness of sustainable land management techniques among landholders and is working on strategies to increase the effectiveness of such knowledge based learning.

Charlie Speirs, Director, Clean Coal Victoria, Victorian Gov. DPI Earth Resources Division
Charlie Speirs has just taken up the position of Director Clean Coal Victoria and will be based in the Latrobe Valley. Charlie has a Civil engineering background with post graduate qualifications in Labour management and an MBA. He has worked for over 30 years in the Latrobe Valley coal industry and for the past decade he has held the position of General Manager Mining at Loy Yang Power. He has grown up in the Latrobe Valley and has extensive knowledge of the local community, the mining industry and the coal resources of the region, which will be of great value as he now starts the work of Clean Coal Victoria (CCV). CCV is part of Victorian Government Department of Primary Industries Earth Resources Division.

Maarten Stapper, BAgSc AgEng PhD FAIAST, Farming Systems Agronomist, BioLogic AgFood
Dr Maarten Stapper is a farming systems agronomist who is passionate about discovering and using the power of nature in food production systems - and the connections between soil biology, soil health, and the overall functioning of agro-ecosystems. He sees many opportunities for Australian agriculture to reverse soil degradation and regenerate soils while remaining productive.
Dr Maarten Stapper has lived, studied and worked in the Netherlands, Canada, USA, Iraq, Syria, and, since 1982, in Australia. He has an agricultural engineering degree from Wageningen Uni, the Netherlands, in farming systems and catchment management in semi-arid tropics. He has a PhD from the University of New England, Armidale, in wheat production systems, linking crop physiology with agronomy and daily weather in simulation modelling.
Maarten worked from 1983 to 1988 at CSIRO, Griffith, on irrigated wheat and introduced irrigation scheduling, a nitrogen fertilizer calculator and the first crop monitoring program for farmers to support their management decisions. He then moved to CSIRO, Canberra, to work on dryland wheat systems and the management of high-yielding irrigated wheat, which led him to the principles of biological agriculture. In April 2007 CSIRO deemed his skills to be "surplus to requirements". Maarten now works as a private consultant assisting farmers in the transition from industrial to biological farming systems.
As a farming systems agronomist Maarten has quantified production in many wheat paddocks in dryland and irrigation districts in southeastern Australia. In that work he has become aware that most problems start with the soil, and thus the search for solutions should commence there. Current soil problems are the result of gross oversimplification of fertilization and 'plant protection' practices that use harsh chemicals and ignore the delicate balance of microbes, trace minerals and nutrients in the soil. Hence GM technology is not the solution to our problems as it only treats individual symptoms and not the wider cause of soil degradation.
The main focus of Maarten's work is helping farmers improve the profitability of their operations by harnessing the power of natural soil processes, improving their use of inputs and understanding those practices that negatively impact on soil health. A healthy soil produces better crops and pastures, requiring less fertilisers and agro-chemicals for similar productivity, and resulting in healthier feed for animals and healthier food for humans.
To achieve this we have to look at the whole farming system - where everything is linked to everything else. Biological agriculture leads to higher biodiversity on farms and a greatly reduced impact on catchments. This process can achieve a doubling of the organic carbon content of the soil, and, if practiced Australia-wide, could capture most CO_2 released in the country and slow climate change.

Jason Stowe, Group Executive Director, The Griffin Group
Jason Stowe is the Group Executive Director of The Griffin Group, one of Western Australia's largest private companies. He has worked across various aspects of the business for the last 15 years, with extensive industry experience including coal mining, energy generation, property development, agriculture, office products and helicopters. Jason has a Bachelor of Business from Curtin University and lives in Perth, Western Australia.

Mr Ehsan Tavakkoli, PhD student in soil & plant physiology in School of Ag, Food and Wine, Uni of Adelaide
Ehsan is a soil scientist and plant nutritionist from Iran, with a Masters degree from UNE on the role of silicon in soils and plants. He is currently completing a GRDC-funded PhD on osmotic and ionic effects of soil salinity on dryland crop production. Ehsan is SA Treasurer of the Australian Society of Soil Science and has a strong interest in sustainable agriculture.

Perry Toms, North American Business Development, Ignite Energy Resources Pty Ltd
Perry Toms currently represents Ignite Energy Resources (IER) and it's sister company Licella in the role of business development in North America. His main focus is on new technology which transforms lignite coal into liquids (such as bio crude oil) and char. The char has potential benefits for agricultural use.
Perry's involvement with non-conventional energy sources began in the late 1980's with TransAlta, who own Canada's largest coal mine. TransAlta's early foresight to look at their carbon footprint prompted investment into projects to develop carbon benefits, such as early carbon trading and waste composting.
Since then Perry has worked with renewable energy at Novera Energy in Australia and Australian BioDiesel Group before joining IER and Licella.

Andrew VanderSluys BA Dip.Str.Mktg, General Manager, LawrieCo
Andrew joined LawrieCo in 2007 and has 25yrs. experience in company reform, building sales teams, strategic marketing and general business management in family based SME's. Prior to joining LawrieCo Andrew was instrumental in a threefold expansion of Laucke Flour Mills in SA and Victoria (in the dual role of General Manager and Sales Director from '99 to '07).

Bruce Ward, Director, Soil Carbon Australia, Pty Ltd
Bruce Ward has a background in large-scale irrigated cropping, having previously been General-manager of Colly Farms Cotton Limited. In 1994 he commenced study in the USA and southern Africa, and introduced the triple bottom line management process, *Holistic Management(tm)* to Australia. Since then he has trained several thousand Australian and New Zealand farmers in that process. Amongst other activities, Soil Carbon Australia creates and disseminates awareness at the farm, community, and political levels about how individuals changing their management decisions achieve more resilient, carbon-rich natural environments.

Dr John D White, Executive Director, Ignite Energy Resources Pty Ltd
Dr John White commenced as Executive Director of Ignite Energy Resources Pty Ltd (IER) (formerly Victoria Coal Resources) in 2006. IER has the rights to a major brown coal deposit in Gippsland, Victoria.
IER plans to integrate leading edge low emissions technologies to create high value energy and biological fertiliser products for domestic use and export.
John was also, until 2008, the Chairman of Global Renewables which was formed in 2000 to pursue greenhouse gas reduction opportunities by providing solutions for waste reduction. Global Renewables has integrated technologies to develop the UR-3R (Urban Resources – Recovery, Reuse and Recycling) Process®.
In September 2005, Global Renewables was selected to design, build, own and operate the Lancashire Waste Partnership PFI project in the United Kingdom. With a revenue of around $6 billion, to process 765,000 tpa of municipal solid waste over 25 years, it is one of the largest waste recycling projects in the world.
John had extensive involvement with Woodside's North West Shelf Offshore LNG Development, he helped instigate the RAN Submarine Project tenders, and subsequently headed the teams that successfully tendered for the purchase of Williamstown Naval Dockyard from the Australian Government, the completion of the Australian Frigate Project (2 FFGs) and the $5 billion ANZAC Frigate Project (10 ANZACs). He was Chief Executive of Transfield Defence Systems Pty Ltd from 1988 to 1996 and then Global Chief Executive of the recycling and packaging group, Visy Industries. He was subsequently Managing Director of the building products and hardware distribution group, Siddons Ramset, until the successful takeover bid by USA giant, Illinois Tool Works.
John has been a Director of a number of publicly listed Australian companies, was formerly Chairman of the Federal Government's Uranium Industry Council, was a member of the Defence Procurement Board.

Tony Wood, Director Clean Energy Program, The Clinton Foundation

Tony Wood has had more than 30years' experience in the fertiliser, chemical, transport and energy industries.
He was Executive General Manager, Corporate Communications & Government Relations for Origin Energy from 2002 until this year. Prior to that, he was General Manager, Retail, for Boral Energy which became Origin Energy after a de-merger from Boral in February 2000.
Tony is on the Executive Board of the Committee for Melbourne, where he co-chaired a Climate Change Taskforce, producing a report earlier this year on the Impacts and Opportunities of Climate Change for Melbourne.
He was seconded to the Garnaut Climate Change Review from March this year until the Final Report was delivered on 30 September.
He has now joined the Clinton Climate Initiative as Director of the Clean Energy Program in Australia. The Clinton Foundation works at the interface between government and business and is focused on delivering accelerated, large-scale solutions to the challenge of climate change. Soil carbon has the potential to contribute, and I am interested in gaining a better understanding of the substance of this potential.

ENDS

THE BASICS OF SOIL ORGANIC CARBON (SOC) IN AGRICULTURE

The capacity for appropriately managed soils to sequester atmospheric carbon is enormous. Soil represents the largest carbon sink over which we have control. When atmospheric carbon is sequestered in topsoil as organic carbon, it brings significant additional benefits to productivity and the environment.

Australia's Soils are in Trouble

"Soil is alive with trillions of minute organisms that recycle nutrients and help plants grow. Soil is the engine room of life. The sun provides the energy, the plants convert and store it and the soil organisms drive the whole system. Australia's soils are in trouble. They are increasingly being poisoned with salt and chemicals. Many areas are compacted and eroded. Our soils are tired and over worked." (Healthy Soils Australia)

Loss of soil organic matter (SOM) / soil organic carbon (SOC) with in Australia's cropping regions following many years of cultivation and cropping has been significant. Long term reductions in SOM often exceed 60% from the top 10cm after 50 years of cereal cropping (Dalal et al, 2001).

On a permanent rotation trial at the Waite Agricultural Research Institute in South Australia soil organic carbon (SOC) in the top 10 cm declined from 2.75% at establishment in 1925 to a mean value of 1.56% in 1993. The greatest declines in SOC were in rotations that included fallow phases, down to a mean value of 1.22%. There are also correlations between declining SOC and yield. (Grace et al, 1995)

"Biophysically appropriate and cost-effective management practices for cereal cropping lands are required for restoring and maintaining organic matter for sustainable agriculture and restoration of degraded lands. The additional benefit of SOM restoration will be an increase in the long-term greenhouse C sink, which has the potential to reduce greenhouse emissions" (Dalal et al, 2001).

What is Soil Organic Carbon? (from CSIRO)

Soil carbon, or soil organic carbon (SOC) as it is more accurately known, is the carbon stored within soil.

It is part of the soil organic matter (SOM), which includes other important elements such as calcium, hydrogen, oxygen, and nitrogen. Soil organic matter is made up of plant and animal materials in various stages of decay.

Un-decomposed materials on the surface of the soil, such as leaf litter, are not part of the organic matter until they start to decompose.

What types of SOC are there? (from CSIRO)

Soil organic matter is often reported in soil tests as the percentage of soil organic carbon present in the soil sample.

However, although determining the amount of soil organic carbon in soil is important for understanding soil health, knowing the type of organic carbon present is also important as this can greatly impact soil productivity.

The CSIRO have identified four biologically significant types or fractions of soil organic carbon; crop residues, particulate organic carbon, humus and recalcitrant organic carbon. Each fraction has different functions, most of these are due to the relative stability and biological availability of each fraction.

The amount of each type of organic carbon in Australian agricultural soils varies significantly.

The proportion of some fractions can also vary due to management practices. This is important as different fractions decompose at different rates and contain different quantities of nutrients, which will have an impact on the health and productivity of the soil.

As discussed further below humus is the most important form of SOC when sequestering atmospheric carbon into a stable form. The CSIRO identify humus as decomposed materials less than 0.053 mm that are dominated by molecules stuck to soil minerals, humus plays a role in all key soil functions and is particularly important in the provision of nutrients - for example the majority of available soil nitrogen derived from soil organic matter comes from the humus fraction.

What is the plant synthesis cycle that deposits SOC?

Building SOC requires two things: green plants and soil microbes. To turn 'air into soil' there are four natural processes; photosynthesis, resynthesis, exudation and humification.

Photosynthesis is a cooling process which takes place in the chloroplasts of green leaves. Light energy (sunlight) is captured and stored as glucose, using carbon dioxide from the air and water from the soil, at the same time oxygen is released into the atmosphere.

Resynthesis describes chemical reactions which process the glucose formed during photosynthesis into a variety of carbon compounds (carbohydrates, proteins, organic acids, waxes and oils). These carbon compounds are 'fuel' for life on earth, eg cellulose for grazing stock.

Exudation 30-40% of the carbon fixed by grass plants during photosynthesis is exuded into the soil to feed soil microbes. The quantity of carbon additions to the soil is relative to the volume of plant roots per unit of soil and their rate of growth. More active green leaves leads to more plant roots resulting in more carbon added to the soil.

Humification is the process which stabilises organic carbon additions so that the carbon exuded from plant roots does not oxidise and recycle back to the atmosphere as carbon dioxide. The process involves soil microbes to transform labile carbon (exuded from plant roots) into stable humic substances. Carbon additions need to be combined with land management practices that promote soil microbes and the conversion of transient forms of SOC to more stable complexes within the soil. Increasing the rate of humification has substantial effects on the health and productivity of agricultural land.

How does the CO_2 to SOC cycle work in Agriculture?

To promote the plant synthesis cycle that deposits stable SOC the most important objective is for agricultural land users to promote beneficial soil microbial activity which will result in an increased rate of humification; the essential final step in sequestering atmospheric carbon into stable SOC.

The methods used in BioLogic Farming Systems (BFS) to promote beneficial soil microbial activity are:

1. Minimise use of chemicals, buffer when application necessary
2. Reduce use of chemical fertiliser, when used stabilise with a carbon source (humic or fulvic acid)
3. Maintain ground cover (stubble/ residue retention and digestion)
4. Increase plant root growth (remember root exudates feed soil microbes)
5. Condition soil with humus based inputs
6. Minimise soil disturbance through tillage

These are achieved while maintaining or improving productivity and profitability, building other soil fertility factors and reducing pest and disease.

The benefits of SOC (from CSIRO)

SOC is part of the Soil organic matter (SOM). SOM is a key indicator of soil health because it plays a role in a number of key functions. These functions can be divided into three types, biological, chemical and physical.

Biological functions of SOM

- provides nutrients and habitat for organisms living in the soil
- provides energy for biological processes
- contributes to soil resilience (the ability of soil to return to its initial state after a disturbance, for example after tillage).

Chemical functions of SOM

- measure of nutrient retention capacity
- provides resilience against pH change
- main store of many key nutrients especially nitrogen and potassium.

Physical functions of SOM

- binds soil particles into aggregates improving soil structural stability
- enhances water holding capacity of soil
- moderates changes in soil temperature.

There are often strong interactions between these different functions. For example, the biological function of providing energy that drives microbial activity also results in improved structural stability and creates organic materials that can contribute to nutritional capacity and resilience to change.

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CSIRO Website

Dr Christine Jones, Amazing Carbon Website

Healthy Soils Australia website

Nitrous Oxide (N_20) emissions from agricultural practices

Agriculture is reported to contribute around 16% of national greenhouse gas (GHG) emissions, accounting for 60% and 85% of total methane and nitrous oxide (N_2O) emissions respectively (FIFA, 2007). The Australian Greenhouse office also predicts that almost 80% of N_2O in the National Greenhouse Gas Inventory is produced by the agricultural sector; of this, 73% is emitted from agricultural soils and 24% from prescribed burning of savannas. Of the total N_2O emitted from agricultural land it has been predicted that 32% results from nitrogen fertilisers, 38% from soil disturbance and 30% from animal waste (Dalal et al., 2003). Similarly agriculture contributes to approximately 78% of the total N_2O emissions in America (Snyder et al., 2007).

Nitrous oxide is produced by microorganisms in the soil, primarily by the processes of nitrification of ammonium to nitrate and denitrification of nitrate (or nitrite) into nitrogen gas. Nitrogen fertilisers, animal manure/urine and nitrogen fixating legumes all contribute to nitrogen inputs (Figure 1). The primary cause of N_20 emissions come from the denitrification process in conditions where a lack of or limited oxygen supply is present. Nitrous oxide production is controlled by temperature, pH, water holding capacity of the soil, irrigation practices, fertilizer rate, tillage practice, soil type, oxygen concentration, carbon availability, vegetation, land use practices and the use of chemicals.

It is well documented that the use of Nitrogen fertilisers has increased as a result of current agricultural practices. Nitrous oxide emissions from agricultural soils are linked to soil management practices and the addition of nitrogen fertilisers. While legumes fix atmospheric nitrogen into plants and soils, they also contribute to nitrous oxide emissions. Symbiotically living Rhizobia in legume root nodules are able to nitrify and denitrify atmospheric nitrogen in the same way as fertilizer nitrogen, producing nitrous oxide.

With so many aspects affecting N_2O emissions, estimates over different agricultural systems vary widely. An equation was given by Bouwman (1994) for calculating the emission of N_20 from different fertilizer sources.
N_20 emitted = 1:25% of N applied (kg N/ha).

Current research examples include: a flooded rice system in the Riverina Plains where N_2O emissions were 0.02% to 1.4% of fertiliser N applied; an irrigated sugarcane crop resulted in 15.4% of N lost over a 4 day period; a dairy pasture system in Victoria showed emissions ranging from 6 to 11 kg N_2O-N/ha; an arable cereal cropping system with N_2O emissions ranges from <0.01% to 9.9% of N fertiliser applications (Dalal et al., 2003). Irrigation and or rainfall events result in high N_2O emissions, especially when N fertiliser is applied with or shortly before such an event (Hansen et al., 1993). Research from an irrigated cropping system in Colorado showed that application of N fertilizer increases N_2O emissions linearly. The effects of urea application on N_2O emissions from pastoral soil in New Zealand also increased N_2O fluxes for up to 30 days (Luo et al., 2007).

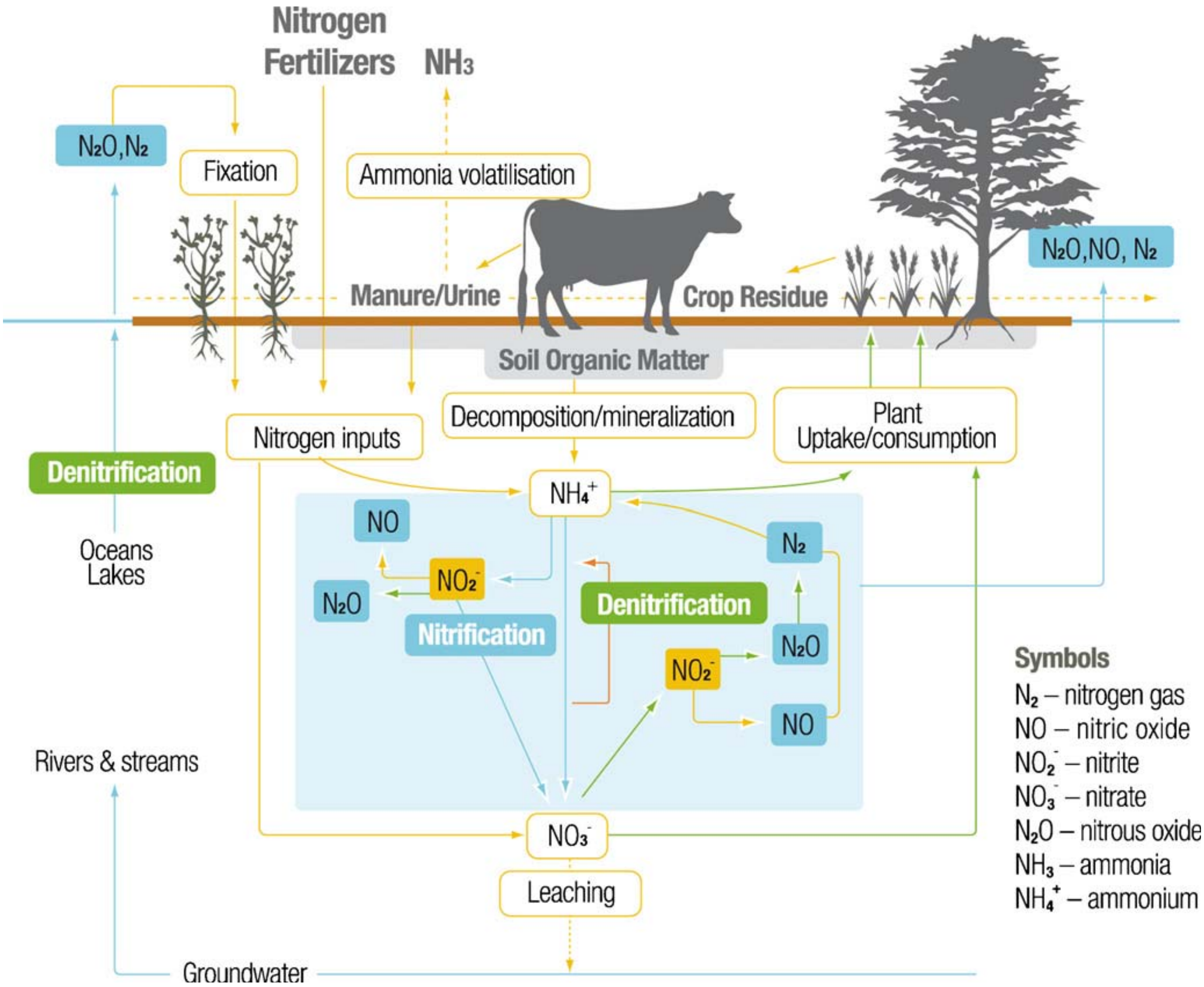

Figure 1: Summary of the Nitrogen cycle (Source: Ugald et al., 2007)

Extract from Dr. Boris V. Levinsky, PhD, Everything About Humates:

“Humates and Chemical Fertilizers

Intensive agricultural systems demand the use of large quantities of mineral fertilizers in order to supply the plants with basic micro-elements, such as nitrogen, phosphorus, and potassium. In doing so, we often forget that mineral fertilizer is for plants what illegal drugs are for sportsmen - you can immediately see high results but tend to ignore the future consequences. The higher the amount of mineral fertilizer used, the more intensive is the erosion of the soil, the poorer the soil’s humus content, and the environment is more polluted. The problem of effective mineral fertilizer assimilation is central in plant-growing. The difficulty of its solution lies in the fact that water soluble potassium and nitrogen fertilizers are easily washed out of the soil, while phosphorus fertilizers, on the contrary, bond with ions of Ca, Mg, Al, and Fe that are present in soil and form inert compounds, which are inaccessible to plants. The presence of humic substances, however, substantially increases effective assimilation of all mineral nutrition elements. It was shown in the tests of barley that humate treatment (with NPK) improved its growth, development, and the crop capacity while decreasing the use of mineral fertilizer. (V. Kovalenko, M. Sonko, 1973.) The tests on wheat showed that one-way use of nitrogen fertilizers on winter wheat crops

did not have a high positive effect on the crop capacity, while its use along with humates and super phosphate achieved an expected positive effect. (L. Fot, 1973.) Interestingly, the mechanism of interaction between humates and micro-elements of mineral nutrition is specific for each of them. The positive process of Nitrogen assimilation occurs due to an intensification of the ion-exchange processes, while the negative processes of “nitrate” formulation decelerates. Potassium assimilation accelerates due to a selective increase in the penetrability of cell membranes. As for phosphorus, humates bond ions of Ca, Mg, and Al first, which prevents the formation of insoluble phosphates. That is why the increase of humate content leads to an increase of the plant’s phosphorus consumption. (Lee & Bartlett, 1973.)
Therefore, the combination of humates and mineral fertilizer guarantees their effective assimilation by plants.” (Levinsky, Dr. Boris V., Everything About Humates, 1999, pp 9-10)

Nitrous Oxide (N_20) and BFS

The information presented outlines the importance of management practices to minimise N_2O emissions from N fertilisation. BFS have demonstrated large decreases in nitrogen inputs through a number of management practices;

1. Reduced application rates, matching crops/pastures need
2. Monitoring plants needs through soil and tissue testing
3. Applying other nutrients if N is required so that supply is balanced and N utilisation is optimised.
4. Practice good crop/pasture management, disease control and soil management to optimise crop/pasture growth.
5. BFS has consistently demonstrated improved friability in soils. This outcome includes less compaction, and higher oxygen levels, both of which provide improved biological activity in soils. Specifically there is evidence that increased activity of endemic microbe species converts to more efficient nitrogen and phosphorous utilisation in plants, along with other key nutrients.

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Reactions of Minerals with Soil Humic Substances

[A summary of a manuscript by M Schnitzer and H Kodama,Soil Research institute, Agriculture Canada, Ottawa, Ontario Canada.]

Humic substances are the principle organic components of soils and waters. The humic substances react and interact with metal ions, oxides, hydroxides and clay minerals to form associations of widely differing chemical and biological stabilities. These interaction products affect the moisture and aeration regime, exchange capacity, nutrient availability, chemical and biological degradation, as well as many other reactions that occur in these systems. The ability of inorganic surfaces to catalyse organic reactions has been overlooked in the past. In soils and waters where relatively large amounts of humic materials are absorbed on hydrous oxide and clay surfaces, catalytic may play more important roles in the synthesis, alteration, and degrading of humic substances than one would conclude from literature where most of these reactions are considered to be of biological nature. The importance of metal-humic and clay-humic interactions in predominantly inorganic soils, with the exception of extremely sandy ones is illustrated by Greenland(1965) which shows that between 52% and 98% of inorganic carbon in a wide range of soils is associated with the clay fraction. It is likely that most of the remaining organic carbon is linked to the metal oxides and hydroxides in the soil.

Humic substances

The organic matter component of soil and waters is a mixture of plant and animal products in various stages of decomposition. These substances are synthesized chemically and biologically from the breakdown of products and organisms in the soil. This complex system is usually divided into humic and non humic substances. Most of the non humic compounds are readily attacked by the microorganisms in the soil and have a short survival rate, [carbohydrates, proteins, peptides, amino acids, fats, waxes, alkenes and low molecular weight organic acids].
The major portion of organic matter in the soil consists of the humic substances. These are amorphous, dark coloured, hydrophilic, acidic, partly aromatic, chemically complex organic substances that range in molecular weights from a hundred to several thousand.
Based on their solubility in alkali and acid, humic substances are partitioned into three main fractions:

Humic Acid (HA) is soluble in dilute alkali, but is precipitated by acidification of the alkaline extract.
Fulvic Acid (FA) is the humic fraction that remains in solution when the alkaline extract is acidified. It is soluble in both dilute alkali and acid.
Humin is that fraction which cannot be extracted from the soil by dilute alkali or acid.

From the data published in literature (Schnitzer & Khan1972) it becomes apparent that structurally the three humic fractions are similar, but different in molecular weight, ultimate analysis, and functional group content. FA has a lower molecular weight but higher content of O-containing functional groups (CO_2H,OH,C=O) per unit weight than the other two humic fractions. Important characteristics exhibited by all humic fractions are resistance to microbial degradation, ability to form stable water soluble and water insoluble complexes with metal ions and hydrous oxides and to interact with clay minerals.

Special role of Fulvic Acid

Of the three principal humic fractions in most soils, only FA is completely soluble in water when ash free at pH values prevailing. In soils, FA accounts for 25%-75% of the total organic matter. (Schnitser 1975)FA is the most suitable humic material for investigating metal organic reactions in soils and water.

Reactions with Metal Oxides and Metal hydroxides

Several workers have reported on the strong solvent activity of humic substances toward minerals, which has significant affects on the weathering cycle and on soil genesis. Humic acid was extracted from Australian podzolic soil. (Baker 1973) The remarkable extracting and complexing power of FA was demonstrated by this research. (Schnitser and Skinner 1963). In soil of high pH, where metals normally form hydroxides, it is the humic substances that are mainly responsible for maintaining sufficiently high concentrations of water soluble metals for satisfactory plant growth. (Rosell & Babcock 1968). Results emphasize the importance of FA in reactions with Al+ in soils. (Schnitzer & Hansen 1975) (Linares & Huertas 1971). For example, the FA promotes the hydrolysis of silicates by the formation of soluble complexes with Fe and Al in Spodosols, until ultimately only a pure silica residue remains in the alluvial horizon. The Al-FA complex migrates downward and under acidic conditions kaolinite and gibbsite are formed.

Conclusion

Humic compounds are capable of attacking and degrading soil minerals by complexing and dissolving metals and transporting them within soils and waters. Especially active in this regard are FA and low molecular weight HA, which are water soluble. At low metal-to-FA or HA ratios, they are water soluble; at high ratios, they are no longer soluble in water.

Humic substances are readily absorbed on soil mineral surfaces. The extent of absorption depends on the geometry and chemistry on the surface, the pH and water content.

FA and low molecular weight HA are adsorbed on external surfaces and interlayers of expanding clay minerals. The magnitude of this absorption depends on pH, being the greatest at low pH, and no longer occurring at pH >5. The main governing reaction seems to be the ability of relatively non dissociated humic materials to displace water from the interlayers. The ease with which water can be displaced depends on the clay mineral and the degree of dissociation of the FA.

In the view of the considerable importance of these interactions in soils and waters, it is hoped that in future soil and water scientists will devote more time and effort to investigate them.

Background

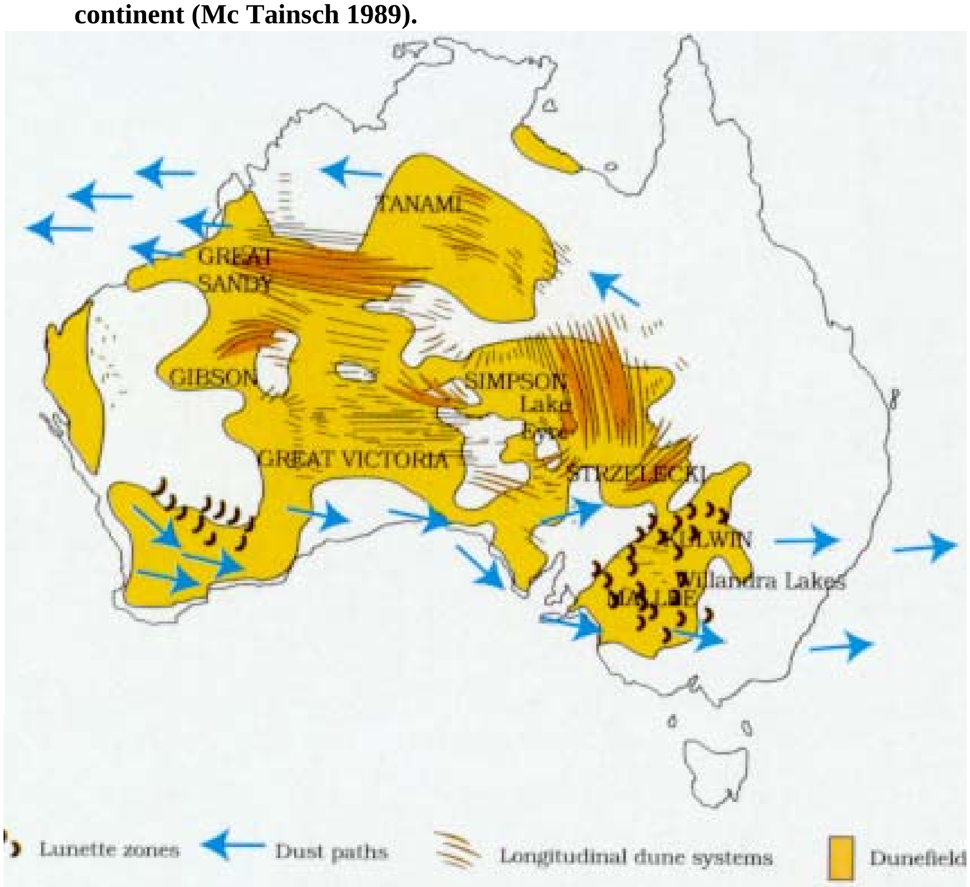
1 Plant requirements

All plants need essential nutrients to grow irrespective of the soil conditions. All plants need nitrogen (N), phosphorus (P), potassium (K), Calcium (Ca), Sulfur (S), magnesium (Mg) and a range of trace elements such as copper (Cu), iron (Fe), molybdenum (Mo), zinc (Zn), boron (B) etc. Maximum plant growth can only be achieved when there is optimum availability of major and micronutrients in the soil. In a native soil environment, such as existed in Australia prior to agriculture, nutrient reserves in the soil were sufficient to sustain a balance between plant use and re-fertilisation from leaf litter. In these ecologically balanced conditions the fertiliser supply was provided to the plant initially in an organic form, and required microbial decomposition in the soil to release the inorganic forms for plant growth. This plant-root nutrient system relies on the formation of stable C compounds that are able to release nutrients slowly over time. With the introduction of agriculture, the balance was changed such that the supply of nutrients from the soil was decreased, because cultivation and burning have seriously depleted soil C levels.

2 Australian soils

Australian soils are composed of ancient rock material, in some cases dating back to 500 million years of age. The landscape has been weathered dramatically over this time period with episodic events lasting for up to 6 months, with wind and water erosion contributing to the major changes as shown in Figure 1. As a consequence, most of our soils are poor in nutrient

Figure 1 Map of Australia showing the influence that wind erosion has had in shaping the continent (Mc Tainsch 1989).



content and require the addition of fertiliser to sustain highly productive agricultural crops. Fertiliser additions have been traditionally in the form of inorganic nitrogen, phosphorus and potassium with the addition of many micronutrients such as copper and molybdenum as required by certain plants. The use of N, P and K and the genetic and agronomic improvements in cultivars over the last 100 years has offset the loss in soil C. Whilst this has enabled the plant to grow more productively, it has led to 39% loss in the productive capacity of soils in Victoria due to inefficient C management.

3 Soil carbon (C) levels

The maintenance and improvement of soil quality is important for sustainable farm productivity. In order to enhance soil quality; proper maintenance of the physical, chemical and biological properties are required and this can largely be achieved through inputs of organic matter to the soil. The average C levels in the soil surface for most agricultural soils are now about 50% lower than what they were in the virgin soil before it was first cultivated. Table I gives an indication of current soil C levels for soils where pasture and cropping enterprises dominate and in high and low rainfall environments in Australia.

Table I General soil organic carbon (SOC) values (g $100g^{-1}$ soil) considered to be low, normal or high for soils used for crop and pasture production in areas of high and low rainfall in Victoria (Peverill *et al.*, 1991).

Soil organic C status	Low rainfall		High rainfall	
	Crops	Pastures	Crops	Pastures
Low (inadequate)	<0.9	<1.74	<1.45	<2.90
Normal	0.9-1.45	1.74-2.62	1.45-2.90	2.90-5.81
High (Optimum)	>1.45	>2.62	>2.90	>5.81

In general, it has taken one and a half centuries of intense human activity to reduce soil C levels to a depleted state in many countries throughout the world. The magnitude of this soil C loss has been exacerbated by soil degradation, especially soil erosion. The long-term implications for the human race are a gradual reduction in the production capacity of soil to grow crops for food, together with an alarming increase in atmospheric CO_2 levels contributing to greenhouse gases. It has been estimated that nearly 100 x 10^{15} g of C have been lost from soil throughout the world due to agriculture (Lal 1999). Figure 2 illustrates the fluxes of C within the soil environment.

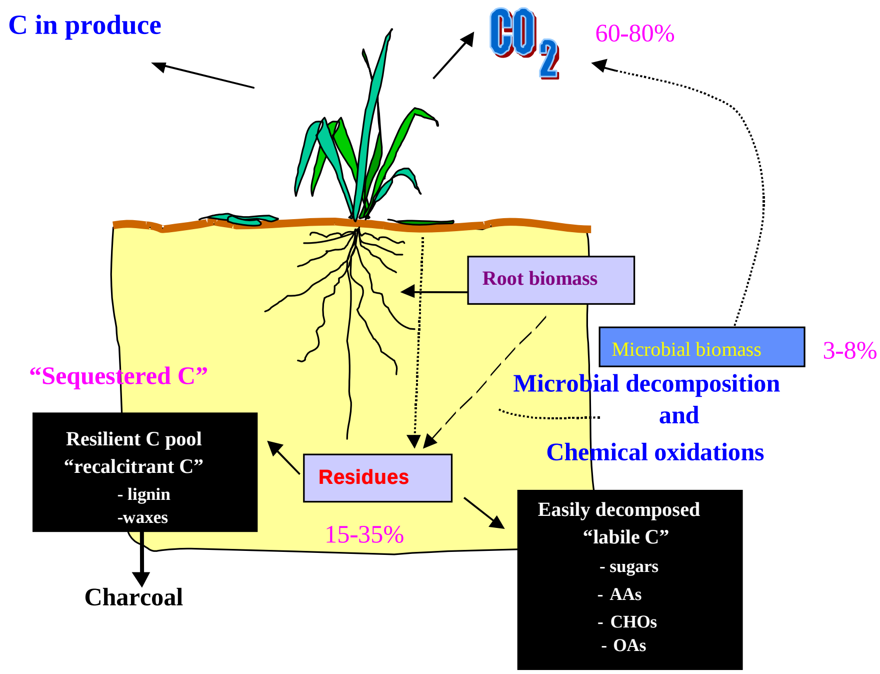


Figure 2 **C cycle in the soil and plant system indicating the major pools of C and their relative stability.**

4 Microbial decomposition of organic matter

Earthworms and other soil animals play an important role in decomposing plant residue material into a litter layer that can then be further decomposed by soil microorganisms. This soil organic matter provides the main energy source for soil microorganisms that are capable of mineralising very complex organic molecules to much simpler substrates and carbon dioxide. In order for plant residues to be assimilated into the soil humus they must first be broken down by the action of the soil microorganisms. Plant residues are composed of a mixture of highly resistant and very labile pools of C. It is now commonly believed that soil humus is primarily composed of humic acids and polysaccharides, which constitute up to 80% of the total soil C (Stott and Martin 1990).

When new C is supplied to soil in the form of plant residues, up to 80% will be lost to the atmosphere as carbon dioxide. It has been shown that the more resistant lignin type structures in various straws will loose between 65% and 84% of the total C as CO_2 within the first 6 months of decomposition. In comparison, C assimilated into new humus by the synthesis of peptides and polysaccharides by microorganisms after decomposition of carbohydrates and proteins in plant residues, will be more stabilised. Therefore, the addition of C in a soluble form to soil as an organic fertiliser derived from the microbial digestion of organic matter will add C to the humus pool that is more stable and likely to result in less loss due to CO_2 respiration (These details are summarised in the Table II below). In general, soil will contain from 2-4% of the total C as microbial biomass, the remainder either being as stabilised humus or as soluble C (Jenkinson and Powlson 1976).

Table II **Fate of different soil constituents after decomposition and assimilation of C into new humus.**

Type of organic matter	**C loss as CO_2 during Ecomposition (%)**	**C assimilation into humus (%)**
Crop residues	70	30
Wheat straw	83	17
Polysaccharides & proteins	70-85	15-30
Soluble C	40-60	40-60

5 Decline in soil C

In agricultural systems it is known that soil carbon levels have declined by an average of 2-3% for high rainfall forest and grassland soils that were at least 5% and by 1% for soils in the low lying plains that were at least 2% in the surface 10 cm soil layer (Slattery and Surapaneni 2001, Klimowitz and Uziak 2001). Figure 3 shows a decline in soil C of 0.7% over the past 40 years in a cropping soil in north-eastern Victoria. It can also be seen that this soil was already below 2% (see Table I) soil C in 1960, and as such was already at a low level of soil fertility.

The loss in soil carbon has led to a decline in soil structure, water holding capacity, microbial activity and the ability of the soil to resist external changes, such as pH. To correct the balances of declining soil carbon in agricultural soil there are two possibilities:

1 - Increase soil carbon levels with long term pasture rotations and/or
2 - Apply new organic materials that will increase soil carbon levels.

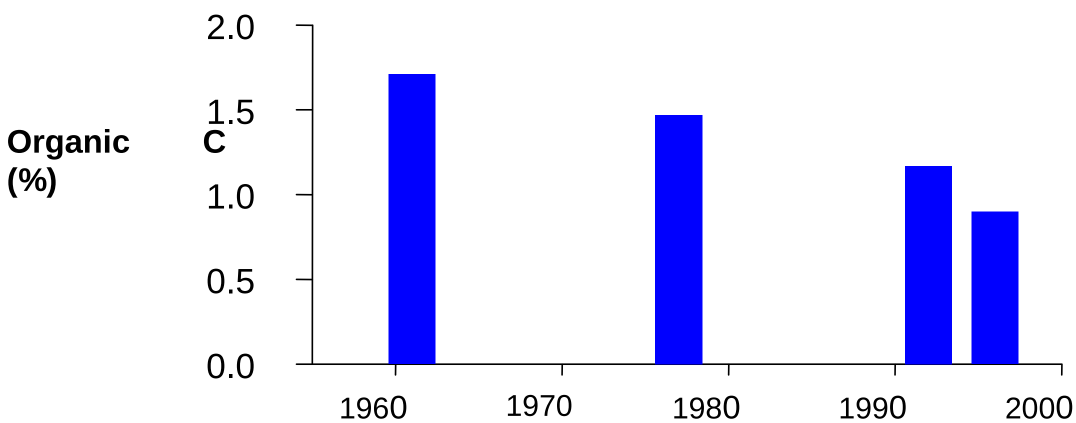


Figure 3 **Soil organic C changes with time for a cropping soil in north-eastern Victoria**

By moving away from frequent cultivation in continuous cropping agriculture, towards soil management practices employing no-till, soil C can be conserved, however, this will not result in an overall increase in soil C levels, as shown in Figure 4b.

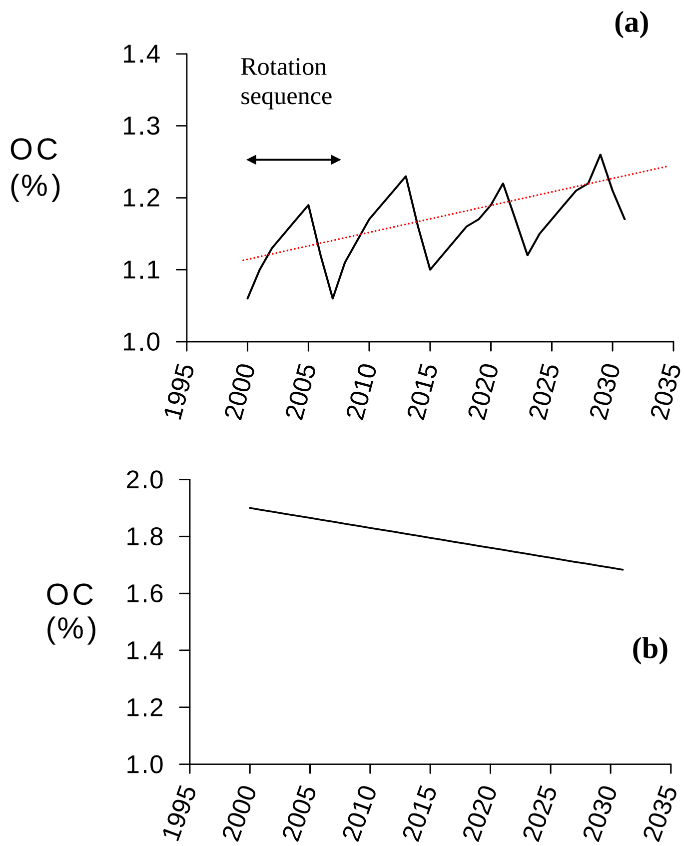


Figure 4 Soil C changes with time for four rotation sequences of (a) 7year pasture +3years of crop and (b) 3years of canola, wheat and oats.

In this example two scenarios have been modelled (soil carbon manager) where in case (a) soil C levels are shown to increase by 0.1% in 35 years with a 7 year pasture phase followed by three years of crop (canola, wheat, oats) using no-till or stubble conservation methods. At current gross returns on agricultural produce, these rotation systems would be uneconomic, because of low wool prices and therefore an unacceptable means of increasing soil C levels. In comparison, retaining current continuous cropping systems as shown in Fig 4b (Canola, wheat, grain legume) again with no-till soil management, will lead to a continual decline in soil C (0.2% in 35 years).

6 How important is Soil C in Australian agriculture?

The benefits of maintaining a higher level of soil C than is currently observed for many agricultural soils are many and varied. Soil carbon and the organic matter, which it is derived from, holds soil particles together and stabilises the soil from the risk of erosion. It aids crop production by improving the soil's ability to store and release air and water as well as nutrients required for the growth of plants and soil microorganisms. By building soil C levels atmospheric content of CO_2 is

reduced, assisting in the reduction of greenhouse gases. Soil C is also very important in acting as a sponge for potentially harmful chemicals that would otherwise find their way into waterways and thus human diets.

Traditional broad-acre cropping systems in temperate regions of Australia involve the farming practices of cultivation and stubble burning. These farming practices have been shown to reduce the level of organic matter (Powlson *et al.* 1987, Haines and Uren 1990, Chan *et al.* 1992) and biological activity (Carter 1986, Wood 1991, Mele 1993) in the soil and to increase the potential for soil erosion (Reganold *et al.* 1990, Carter and Steed 1992). These farming practices increase the potential for soil structural degradation to occur, in that they disrupt soil structure by reducing water infiltration (Carter and Steed 1992, Carter *et al.* 1994, Bissett and O'Leary 1996) and soil aggregation (Boyle *et al.* 1989, Tisdall and Oades 1982), leading to increased water runoff and losses in surface soil by either water or wind erosion. A detailed list of soil changes brought about by increasing soil organic matter is given in Table III below.

It has been shown that farming practices that involve the use of stubble burning and conventional cultivation (breaking of the soil surface with a tyned implement to prepare a seedbed and reduce the weed burden in preparation for the sowing of a crop) will reduce the total amount of organic C compared with methods that retain stubble and direct drill crops into uncultivated seedbeds (Dalal 1989, Chan *et al.* 1992, Slattery and Surapaneni 2001).

Table III Soil changes influenced by increasing soil organic matter.

Soil change recorded	Reference
Increased microbial biomass	Powlson *et al.* (1987), Haines and Uren (1990), Wood (1991), Chan *et al.* (1992), Mele (1993).
Increased microaggregates	Skjemstad *et al.* (1990), Tisdall (1991).
Increased resistance to erosion	Carter and Steed (1992).
Increased cation exchange capacity	Kapland and Estes (1985), Chan *et al.* (1991).
Increased FA[A], HA[B] and polysaccharides	Boyle *et al.* (1989).
Increased carbohydrates, amino acids	Arshad *et al.* (1990).
Increased aliphatic C	Arshad *et al.* (1990).
Decreased aromatic C	Arshad *et al.* (1990).
Decreased phenolic acids	Suflita and Bollag (1981).
Decreased Al toxicity	Evans and Kamprath (1970), Ahmad and Tan (1986), Hue *et al.* (1986).
Increased Al-complexes with organic acids	Bartlett and Riego (1972), Suthipradit *et al.* (1990).
Increased soil pathogens - Take all - *Rhizoctonia* root rot - *Pythium* root rot	Cook and Hagland (1991), Heenan *et al.*(1995).

[A]fulvic acid, [B]humic acid

The soil is a dynamic living environment, which provides a matrix for the reaction and interaction of many physical, biological and chemical factors. Organic matter within the soil represents all of the living, dead and decomposing plants, animals and microorganisms as well as the organic residues and humic substances they release (Tisdall 1991). In order to conserve this biological diversity within farming systems that employ cultivation and broad-acre monoculture, we must move to alternative systems that prevent this decline in organic matter but at the same time maintain agricultural productivity. These alternative systems could include the use of concentrated humic materials that will reduce the cost of transportation and therefore become economic options. The use of intensive agricultural practices such as stubble burning and cultivation are also likely to upset the delicate balance between sustainability and degradative processes within this soil matrix.

The relationship between soil management and soil structure is diagrammatically presented in Figure 5. Soil structure determines the physical environment in which the plant roots survive by controlling water supply, aeration, nutrient availability and physical constraints. In turn the plants, together with other inputs of organic residues will control the stability of the soil, thus preventing or reducing off site impacts to create a sustainable farming system.

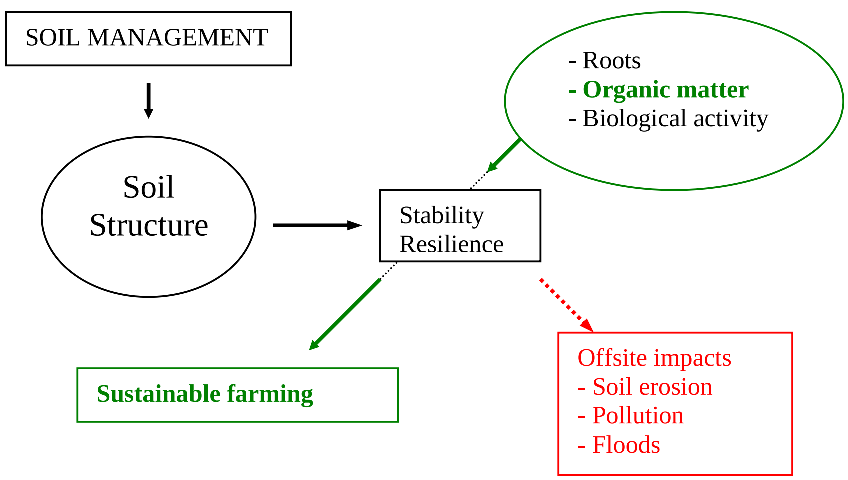


Figure 5 Soil structure and sustainability

Environmental factors such as landscape and climate are also important for maintaining soil stability and resilience in the ecosystem; for example, high rainfall areas (>600 mm p.a.) are subject to much greater nutrient losses by leaching than moderate-low rainfall areas (<400 mm p.a.) (Addiscott 1988). Organic and biological diversity within the soil is very much dependent upon the type and intensity of agriculture being practised. Thus, the organic matter residues in a permanent bed pasture soil would be significantly different to those in a continuously cultivated cropping soil. It might be expected that these differences in C would influence the microbial populations that derive a significant proportion of their energy needs from C residues.

The sequestration capacity of a soil for organic C is dependent mainly on climate, soil type and landscape (edaphic conditions), type of vegetation/farming and soil management (Carter 1996). Reductions in soil organic C has focused mostly on traditional agricultural systems (e.g. tillage, stubble burning) involving soils used for cropping and grazing enterprises. For example, reduced tillage operations (conservation farming) in arable farming systems, either alone or in conjunction with cover crops, offer scope for the build up of organic C levels.

7 The use of organic fertilisers

The application of composted organic matter onto broadacre agricultural farming enterprises has always been a problem due to the cost of transport. However, the use of a high nutrient value organic fertiliser provides an opportunity to increase soil carbon and supply a source of nutrients for plant growth. A benefit of organic fertilisers over inorganic fertilisers is the ability to release nutrients slowly over a longer period of time. Whereas, inorganic fertilisers release massive amounts of nutrient in an inorganic form that can become bound through chemical reactions to clay and organic matter surfaces, whilst at the same time creating an environment that may not be conducive to microbial growth. We do not know what the impact of concentrated humic substances will be on the build up of soil C and the increase in microbial biomass, this will need investigation. In addition to adsorption, inorganic fertiliser application can result in large losses through surface runoff and subsoil leaching. In fact up to 40% of losses in high rainfall grazing systems can be directly attributed to inorganic fertiliser application (Nash and Halliwell 1999).

Organic fertilisers have an unknown nutrient potential for a range of agricultural crops under different environmental conditions. The production and sale of organic fertilisers is an emerging industry arising from a need to reduce the cost of waste disposal from agriculture and food production. A desire to re-use valuable nutrients in products currently disposed of in landfill and in response to the increase in world demand for organic produce will enhance our environment.

8 Agricultural history of yield responses to fertilisers in Australia

The changes in farming practice have reflected the developments in agricultural research brought about by declining soil fertility and a need to remain economically viable. Figure 6 illustrates the changes that have occurred in Australian agriculture and identifies particular events that have led to an increase in crop production (Donald 1965, Angus *et al.* 2001).

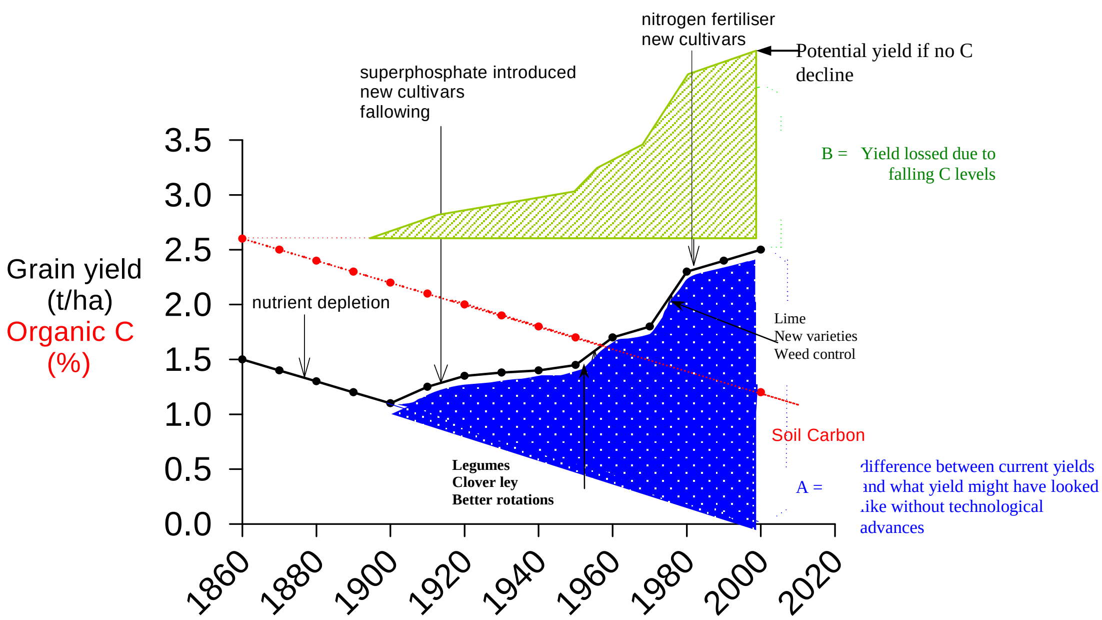


Figure 6 Changes in wheat yield each decade from 1860 to the present (Angus *et al.* 2001)

For the first half of the last century after the introduction of superphosphate fertiliser, yields rose steadily until nitrogen became limiting. Nitrogen fertility was improved with clover ley farming in the early 60's to be replaced by legume crops in the rotation in the late 70's. This led to increased soil acidification and the need to lime in acid soil environments such as in the high rainfall regions south eastern, northern, western and southern Australia. Together with the introduction of new acid tolerant varieties and better weed control, grain yields rose to even higher levels. Then with the introduction of new cultivars and better nitrogen fertiliser practices (time and rate of application) grain yields have risen to a new average maximum in 2000.

However, during this entire period soil fertility, with respect to soil carbon and microbial activity, have declined. In scenario A (Figure 6) the difference between grain yield without technological inputs and current yields is about 2.5 t/ha. In scenario B the potential yield for soil that did not decline in soil C over the past century is about 4 t/ha with technological inputs. It is speculated that the next dramatic gains in crop production will come from increasing the biological activity of soil and accessing nutrients through microbially driven mechanisms. This will be unachievable if the energy required for microbial growth has become almost totally depleted or in such a form that it is virtually inert to microbial decomposition. For this reason we suggest that the introduction of organic fertilisers will at the very minimum begin to build soil C levels and is likely to result in a further increase in grain yield or grain protein content. An alternative view is that biotechnology will provide the solutions for the next large increases in productivity. However, without improvements in soil fertility and resilience to further degradation these technological improvements in plant production will not be realised.

An estimate of the maximum potential of a soil to produce grain yields can be determined from the water use efficiency of that agroecological zone. For example a crop grown in the arid Mallee region will have a much lower yield potential than a crop grown in the 600 mm rainfall zone. This is illustrated in Table IV below.

Table IV **Maximum potential grain yields for wheat for different agroecological zones based on water use efficiency.**

Agroecological zone	Annual average rainfall (mm)	Maximum potential grain yields (t/ha)	Current average grain yields (t/ha)
Arid sands	<200	2.0	1.0
Murray Basin (sandy loams)	200-250	3.5	1.5
Lower slopes - plains	250-550	5.0	2.5
Upper slopes	550-650	8.0	4.0
Alpine and coastal	>600	10.0	6.0

In order to achieve these high yields there is an assumption that all essential plant nutrients will be available. In Australia, the need to conserve the limited surface soil is of utmost importance. In order to do this we must focus on the management of the topsoil and the retention of soil C will be an important factor. When we compare the soil C levels of European soils to Australian soils we find that European clay loam soils are typically 10-28% organic C compared to Australian clay loams of around 3-5%. This means that European soils contain a higher capacity to retain nutrients, increase water-holding capacity, improve soil structure and higher microbial populations. All of these factors together with a higher annual rainfall result in higher average wheat grain yields in the order of 10-

12 t/ha with a potential maximum of around 16 t/ha (for European soils). Clearly, the challenge to emulate these yields is difficult in the Australian climate that consists of low annual rainfall and shallow fertile soil layers. Increasing soil C levels is a major step towards this goal, as this would provide the capacity to increase the water use efficiency of the plant by storing more soil water and increase the retention of nutrients in a complex soil-organic matter matrix that also creates better soil structure.

In two scenarios of what the future might look like, we propose that soil C values could (a) increase if sufficient inputs of C were applied or (b) decline at a similar rate to current C depletion rates. In Figure 7a grain yields are predicted to rise with increasing soil C values whereas in Figure 7b grain yields begin to decline or remain the same with no further advances in soil health, but may continue to increase with advances in breeding technology (line A) or where growing season rainfall is non-limiting (line B).

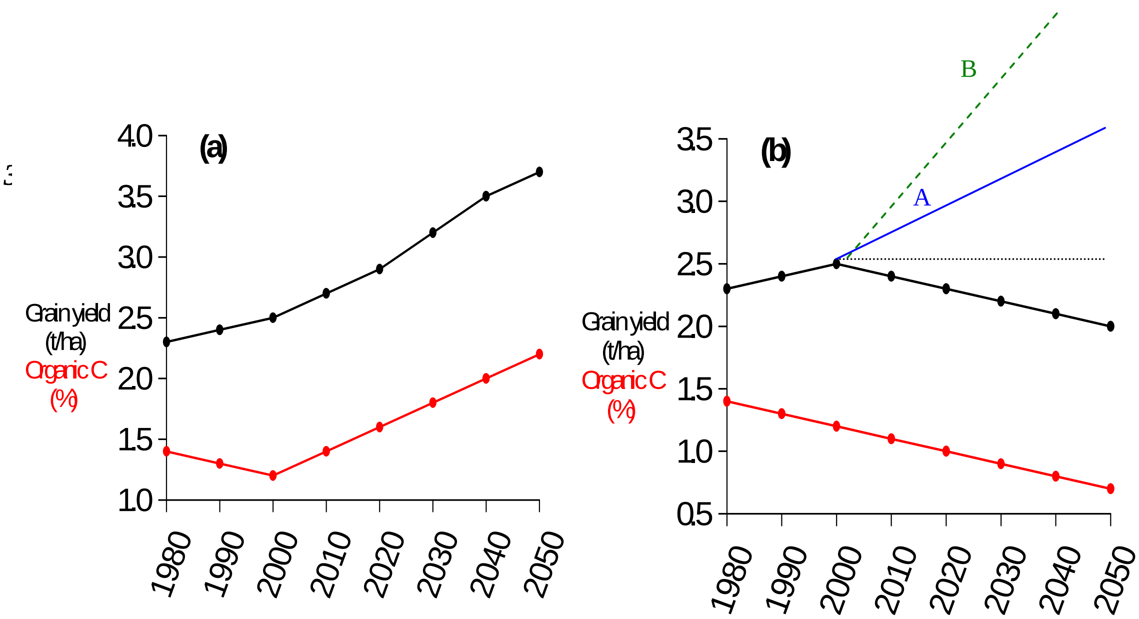


Figure 7 Predicted change in average grain yields for wheat, as soil C levels change. Line A represents advances in biotechnology and Line B represents non-limiting growing season rainfall.

9 Influence of Farming Practice on Soil Carbon Levels

Under minimum tillage or no-till farming systems, it has been observed that there is a higher proportion of aliphatic C compounds (70-89%) than aromatic C compounds (6-23%). These aliphatic compounds are much more easily degraded by soil microorganisms, which will eventually lead to a higher availability of nutrients to plants. High temperatures and precipitation provide conditions that are conducive to the proliferation of soil microorganisms and the subsequent mineralisation of soil organic matter to simple compounds and eventually the liberation of carbon dioxide (CO_2). Under these conditions of high microbial activity, the humic acid fraction will have a low aromatic content (Skjemstad *et al.* 1983), and a higher nutrient availability. However, soils with low microbial activity will produce a soil with its organic matter high in aromatic content (Wilson 1990). The higher proportion of aromatic C (approx 50%) in the conventionally cultivated soil means it is also generally less biodegradable (Arshad *et al.* 1990, Krosshavn *et al.* 1990), and

nutrients will be less available. This concept is illustrated in Figure 8, where the fate of organic matter into humic and fulvic acids is shown.

Respiration studies with ^{14}C-labelled CO_2 showed the resistance to biodegradation was much greater with C atoms present in ring structures than C atoms present in amino acids, amino sugars and as side chains on phenolic compounds (Martin and Haider 1980). This finding is consistent with the view that recently formed (<10 yrs) humus contains higher concentrations of amino acids, amino sugars and more N compounds (Jenkinson 1971), polysaccharides (Oades and Wagner 1970) and phenolic compounds (Martin *et al.* 1974) and will decompose faster than older humus. These would be termed the non-humic substances (Figure 8). Therefore, the introduction of humic substances from biologically derived organic materials such as organic fertilisers, will be a source of newly formed humus. This humus will be easily decomposed by soil microbes and provide a slow release source of nutrients over the growing season rather than all at once, as with inorganic fertilisers. On the one hand these nutrients will be available for plant growth, but on the other this new C may be lost as respired CO_2.

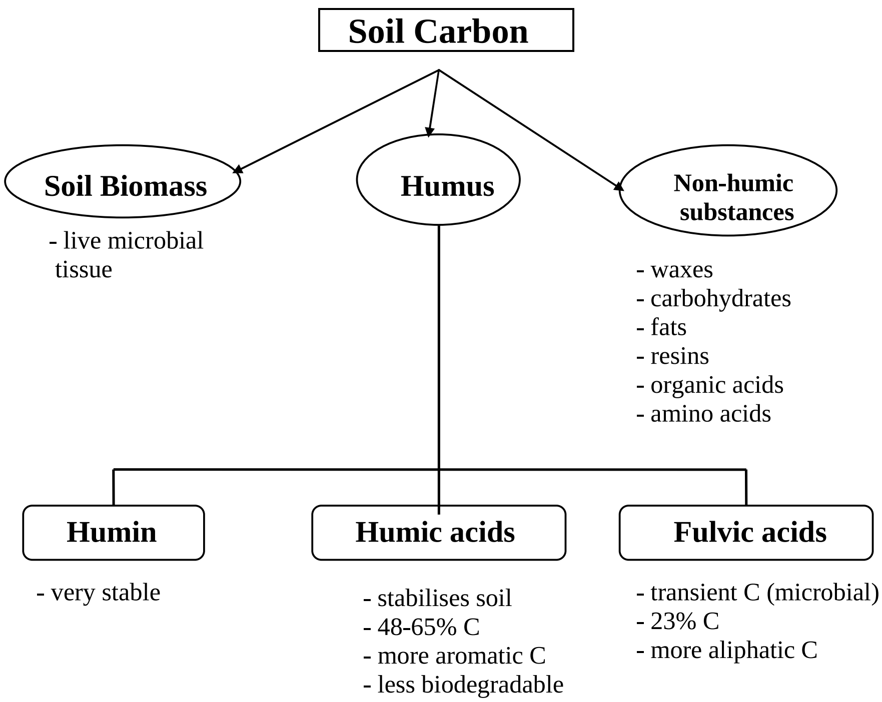


Figure 8 Fate of soil carbon into the various humic and fulvic acid pools.

There is a possibility that new C will have higher turnover rates in organic fertiliser treatments with no-till compared with conventional fertiliser treatments using tilled or burnt practices, due to the higher soil microbial biomass, and consequently higher proportion of soil C remaining as aliphatic structures. In continuous cultivation farming practices that have taken place in Australian agriculture over the past 70-100 years, there has been a gradual decline in soil C (Grace *et al.* 1995, Heenan *et al.* 1995). For these systems, it is possible that the more resistant soil C pools referred to as 'humin' by Kononova (1966) have been mineralised to increase the intermediate and soluble C pools as the total C pool declines. This depletion of resistant soil C may have a long-term effect on reducing the soil's overall cation exchange capacity and hence its ability to retain nutrients and remain fertile.

Any agricultural practice that enhances soil drying such as burning, exposure by ploughing, wide tillage spaces or bare fallows will hasten the loss of soil C as respired carbon dioxide. This is illustrated diagrammatically in Figure 9, where protected soil C would be that C below the soil surface in a no-till farm management system.

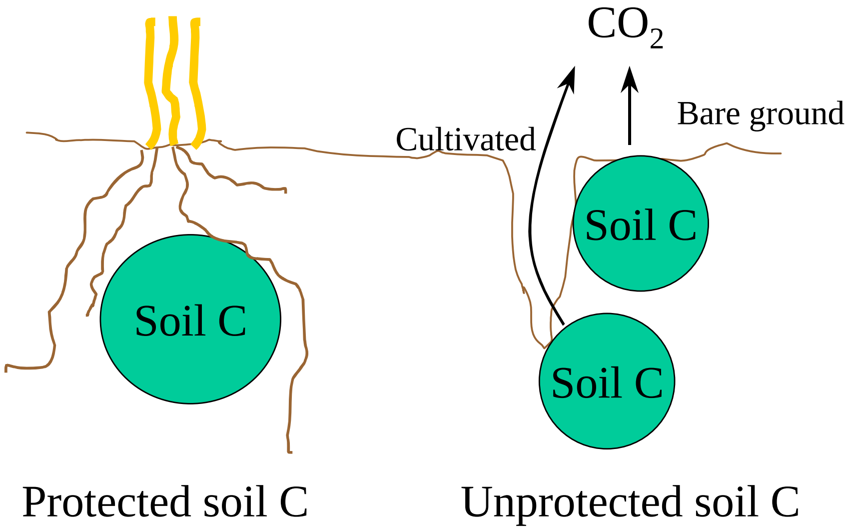
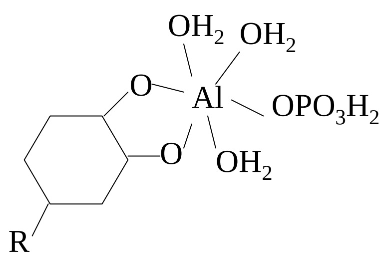


Figure 9 Diagrammatic representation of protected soil C compared with exposure due to tillage, burning and bare soil.

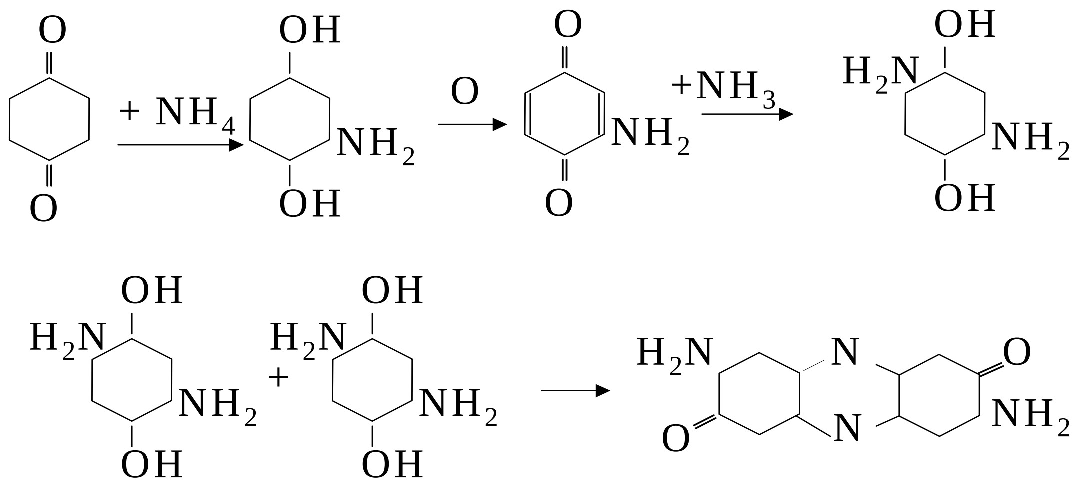
The capacity of soil organic matter to retain nutrients will be dependant upon their chemical structure and functional groups that determine reactivity towards other compounds and elements. For example C compounds that are high in aromatic structures have the capacity to bind metals very strongly due to their stearic arrangement as shown by the following formulae.



In addition, as shown by this diagram, metal chelates that bind to organic compounds act as a link between phosphate and nitrate anions and the negatively charged humate molecule. The higher the concentration of carboxylic acid groups on the organic matter surfaces, then the higher the cation exchange capacity (CEC) of this organic material. This means that organic matter high in CEC will be able to bind with more nutrients and thus act as a sink for slow nutrient release in the soil. For this reason it is better to apply organic matter that has a high base saturation and is able to consume protons from the soil solution and thus raise soil pH whilst giving up cations for plant growth. This is shown in the following reaction.

$$R-\overset{O}{\overset{\|}{C}}-O-Mg-O-\overset{O}{\overset{\|}{C}}-R + 2H^+ \longleftrightarrow 2(RCOOH) + Mg^{2+}$$

During mineralisation of organic matter, fixed N can be made available to plants only when it is attached externally to aromatic or aliphatic structures and becomes less available when polymerised into ring structures as shown in the following reaction.



However, some microorganisms are able to oxidise ammonium directly to produce nitrite and then nitrate which is available for plant root uptake according to the following reaction sequence.

$$R-NH_2 \xrightarrow{\text{Nitrogenase}} NH_4^+ \xrightarrow{\text{Nitrosomonas}} NO_2^- \xrightarrow{\text{Nitrobacter}} NO_3^-$$

The availability of N is dependent upon the form in which it is supplied to the soil. If N is fixed or polymerised into C structures it will be largely unavailable however, if it is adsorbed or weakly bound to carbonyl groups then it will be more easily attacked by soil microorganisms. The formation of humic acids in soil provides a material that is likely to contain more aromatic structures than aliphatic structures and consequently will be more stable and resistant to decomposition (Khalili and Ajjouri 1987). The formation of humic substances that contain high amounts of aromatic C are related to the amount of fungi in the soil (Baldock et al. 1990). So it would be reasonable to assume that humic acids derived from a process dominated by bacteria will contain structures that are more easily biodegraded. It should be pointed out however, that the stable humus would form nutrient reserves as well as contribute to the maintenance of aggregate stability and ultimately protect the soil from erosion and nutrient loss.

10 What is the optimum level of soil C?

Current data suggests that soil C values were significantly higher than what they are today, as already shown in Figure 3. In addition, the changes in soil C are related to environmental factors such as rainfall and vegetation cover. Figure 10 shows the geographical changes in soil C from high rainfall alpine slopes to the arid desert plains. The age of these soils is also an important factor in determining soil C content. For example alpine soils are derived from more recent volcanic activity and are considerably (about 100 million years) younger than the soils from the arid centre.

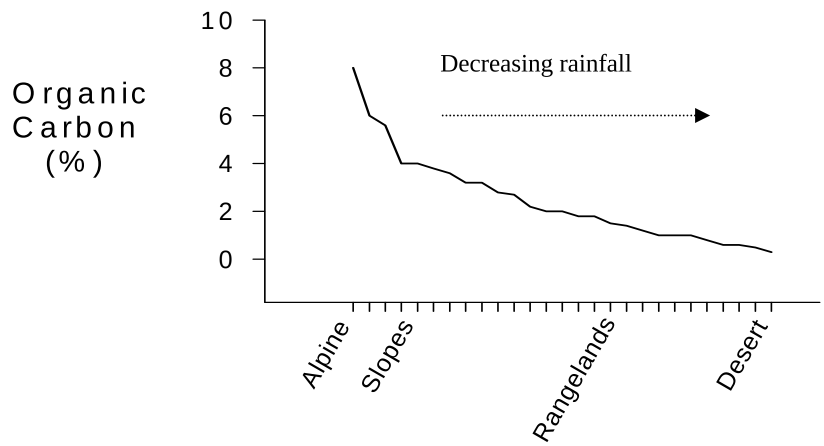


Figure 10 Soil C changes with topography and rainfall.

The maximum potential soil C level for any given soil then, will largely depend upon where that soil is located within the landscape. In addition, the management of soil will play a vital role in determining the new equilibrium level of soil C, especially if soil C is increased rapidly with organic fertilisers or composts compared with the slower increase through long-term pastures. For a range of cropping soils located in the northern half of Victoria (Figure 11) on seven soil types it was observed that farmers adopting conservation farming practices of no-till and long-term pasture rotations could achieve soil C levels approaching 3% (Figure 12).

The amount of C a soil will be able to sequester will also be governed by the functions of different microbial groups within the soil. For example some components of soil organic matter will be related to structure whereas other components will be related to nutrient release, e.g. mineralisation. Thus at any given point in time the net balance of soil C remaining in the soil will be the difference between decomposition and stabilisation of the organic matter pool. Figure 13 illustrates the inputs and outputs of the C cycle where the remaining C will be divided between charcoal, humic and fulvic acids within the soil matrix.

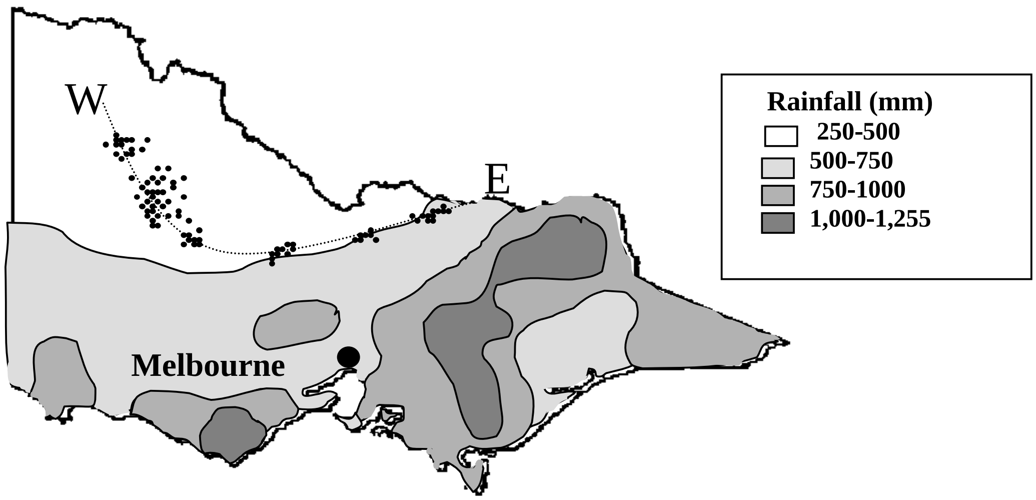


Figure 11 Location of the long-term experimental sites in the Rutherglen and Tatura regions and the location of the 117 survey sites (●) across the northern cropping region of Victoria.

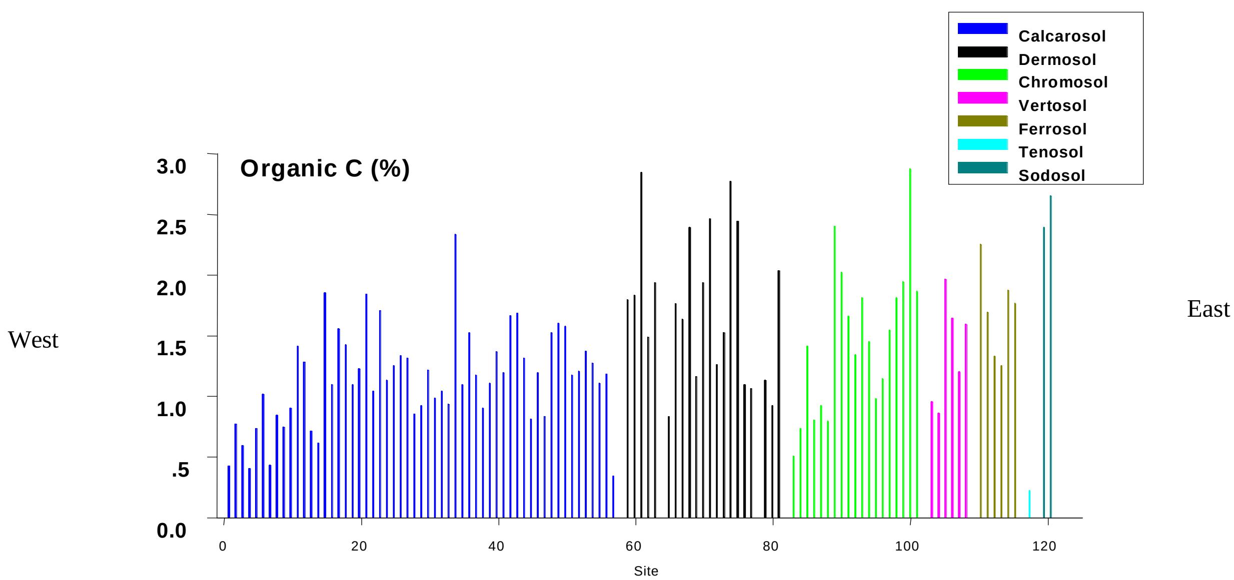


Figure 12 Soil organic carbon values in the surface 10 cm of soil for a range of soil types sampled in 1997 across the northern cropping region of Victoria, Australia (West to East).

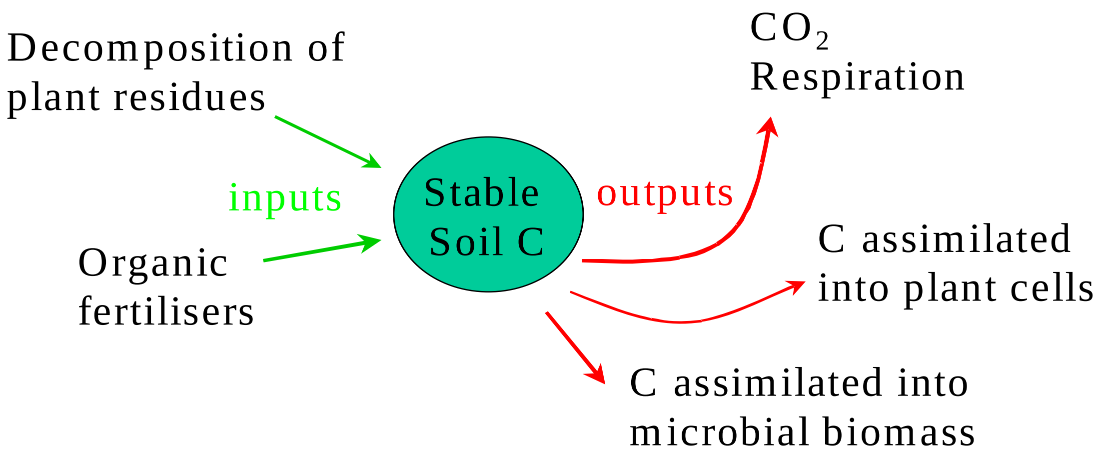


Figure 13 Stable soil C will be the difference between inputs and outputs.

The addition of soil organic matter has been shown to decompose rapidly, where mineralisation and decarboxylation reactions dominate. This means that a large pool of the soil C is lost as carbon dioxide within the first few weeks of being applied to the soil, providing that soil moisture is not limiting. These losses could be as high as 80% depending upon the soil microbial population and the form of organic matter applied to the soil. For stabilised humus products we do not know what this rate of decomposition will be nor the loss of carbon dioxide released to the atmosphere or the actual increase in soil C. Further work is needed in this area to demonstrate the real benefits of humus materials over that of other organic fertilisers.

Importantly, attempts to increase soil C with the addition of stabilised organic matter have been successful, and the addition of composted bovine manure at a rate of 109 t/ha of dry material, elevated soil C values by 1% in the surface 10 cm of soil. Although the losses of soil C in this study were high (70-80%), the increase in soil C has been sustained over a three year period (Slattery and Carmody 2001).

11 How can we increase soil C levels?

Many Australian agricultural soils contain less than 1% soil C. In Victoria, there are 2.35 million ha of cropping land with approximately 22% of this area burnt annually and another 65% with some form of soil disturbance through cultivation and/or stubble mulching. These soils will lose the most soil C at a rate of about 0.04-0.10 g/100g soil (Table V). This means that it will take 60 years to reduce a soil of 3.5% soil C in the surface 10 cm soil layer, to a level of 1% under stubble burning farming practices.

However, the same soil that is cultivated and continuously cropped will only take 20 years to decline in soil C from 3.5% to less than 1%. Given that soils in the Mallee and northern areas of Victoria have been cropped for at least 60 years, we can safely say that at least half of the cropped soil or 1.2 million ha now have a soil C level of less than 1%. In order to raise the soil C level by 1% in the

surface 10 cm soil layer we require additions of 10 tonne of C/ha, assuming no loss of C as carbon dioxide from microbial decomposition and respiration. On the other hand if we lose 80% of this C as carbon dioxide, then we will need to add 50 t/ha of C to the soil.

Table V Annual soil C changes due to different soil management practices (Slattery and Surapaneni 2001)

Management Practice	***Change in C (%) yr^{-1}***
Stubble standing	- 0.007
Stubble shredded	- 0.004
Stubble standing + lime	- 0.040
Stubble burnt	- 0.043
Stubble mulched	- 0.052
Cultivation	- 0.1
Stubble stand + clove)	+ 0.0001
Pasture	+0.04 to +0.08

Assuming that additions of C are managed over the long-term, then application rates of organic fertiliser can be applied at more realistic rates of 2500kg/ha/yr to achieve an increase of 1% C in the surface soil layer within 20 years. However, if the decomposition rates are also much reduced, then it is likely that less organic fertiliser will be required because of the more stabilised humus product, and an application rate of 500kg/ha/yr for 20 years might be sufficient to raise soil C levels by 1%. Further research to identify the rate of decomposition of organic fertilisers derived from humus is vital in determining these annual rates of application.

The sequestration of C under permanent pastures will increase soil C at the rate of 400-800 kgC/ha/yr or 0.04-0.08% and will require 13-25 years to achieve an increase of 1% C in the surface 10 cm of soil. This may be a more viable option for many soils, but requires the land to be removed from crop production. These predictions can be summarised in the following Table VI where several different crop and pasture rotations are considered together with an optimistic rate of 45% decomposition to carbon dioxide. Clearly here the application of humic acid with a permanent pasture is the optimum strategy to increase soil C levels quickly. However, it is important to note that even with continuous cropping the application of humic acid will increase soil C levels over the long term.

Table VI **Years to sequester 1% soil C when different amounts of HA are applied to 3 different farming systems.**

Farming system	C sequestration rate	Years to increase soil C by 1%
Permanent pasture (PP)	0.04%/yr	25
PP + 250 kg/ha of HA (70% dec rate)	0.047%/yr	21
PP + 250 kg/ha of HA (45% dec rate)	0.054%/yr	18
Crop (no till) (CNT)	-0.007%/yr	Gets worse
CNT + 250 kg/ha of HA (70% dec rate)	0%/yr	stable
CNT + 250 kg/ha of HA (45% dec rate)	0.007%/yr	71
3 yrs Crop + 5 yrs pasture (CP)	0.179%/8yrs	45
CP + 250 kg/ha of HA (70% dec rate)	0.189%/8yrs	42
CP + + 250 kg/ha of HA (45% dec rate)	0.199%/8yrs	40

Stabilisation of soil organic C will be dependant on several factors, which include the rate of residue input, the rate of decomposition, the fate of the C and N pools, the degree of soil disturbance and hence the mineralisation of these C and N pools. For humus products, and for that matter many organic fertilisers, we have limited knowledge of these processes and the long-term fate of C after soil amendment. In manure amended soils the level of both soil C (increased by 0.2% over conventional systems) and N were shown to have increased after 10 years of continuous application of manure, equal to a rate of 6.5 t/ha/yr of dry product (Wander and Traina 1996). In another study (Slattery *et al.* 2001) soil C was increased by 1% in the surface 10 cm soil layer after a single addition of 109 t/ha of dried stabilised composted bovine manure.

It is well established that native humic substances play a major role in the accumulation of new organic matter to soil by chemically protecting the most labile molecules released during decomposition of plant tissue from immediate microbial mineralisation (Baldock *et al.* 1989, Spaccini *et al.* 2000). For a fertiliser product that is largely humic acid in nature, once stabilised within the soil matrix, it will contribute to the long-term accumulation and stabilisation of soil carbon and become a sink for newly degraded organic matter. However, it is the unknown reaction of added humus to soil mineral and organic matter surfaces that will determine if the process of C accumulation is dominant, or in fact if microbial decomposition and subsequent carbon dioxide respiration and N and C mineralisation are the dominant processes. Humic acids contain around 59% C and this must be taken into account when estimating rates of application that will increase soil C levels.

Clearly there are some very important factors that control the rate of stabilisation and subsequent long-term release and exchange of nutrients in the soil from organic materials used as soil conditioners. These include the following;

- size of the residues entering the soil,
- size and composition of the microbial pool and subsequent oxidation,
- rate of decomposition, mineralisation and nutrient leaching,
- degree of cation saturation of the organic fertiliser and therefore nutrient adsorbing capacity,
- initial pH of the organic fertiliser in relationship to the soil pH,

- C:N ratio of the organic fertiliser,
- C and N content of the soil being amended,
- total C supplied in the organic amendment and
- placement of the product (surface or subsurface).

Provided all of these conditions are optimal, and at this stage only some of these aspects are known for some soils, then we can estimate the annual requirements to both achieve high soil C levels and subsequently maintain a sustainable farming system. This information is summarised in Table VII for three cropping practices.

The preferred option for most cropping soils would be to adopt the conservation farming practice of retaining standing stubbles and reduce the total losses of soil C from the soil.

Table VII **Carbon sequestration rates under different crop management practices and the rate of organic fertiliser (OF) (based on 59% C in humic acid) required to a) increase soil C by 1% and b) maintain a sustainable framing system having reached a soil C level of 2%.**

Management practice	Start Level of OrganicC (%)	Annual soil C loss (t/ha)	(a) Input of OF required to raise soil C by 1% (t/ha)	(b) Input of OF required to sustain current soil C level (t/ha)	Cost of application per hectare at a rate of $75/t spread (a)	(b)
Cultivation	**1.0**	**1.0**	**17**	**1.70**	**$1275**	**$128**
Burning	**1.0**	**0.4**	**17**	**0.68**	**$1275**	**$51**
Stubble standing	**1.0**	**0.07**	**17**	**0.12**	**$1275**	**$9**

An estimate of the C content of various organic materials that have been used to increase soil C is given in Table VIII. In this Table, values are given for the amount of product required per hectare to increase soil C levels by 1%. From these data it can be seen that bulk materials of woodchip, peat, paper waste and peat are all high in organic C, but are likely to be low in other nutrients especially phosphorus.

Table VIII **Carbon sequestration rates for different organic fertilisers based on best estimates of organic carbon content.**

Fertiliser	**Total C content of product (g/100g) (%)**	**Estimated volume of product required to provide 10t of C/ha = 1% (t)**	**Estimated rate of application per hectare to reach 1% (assuming 70% loss) (t/ha)**
Peat	**47**	**21**	**70**
Woodchips	**48**	**21**	**70**
Poultry manure	**46**	**22**	**73**
Wheat straw	**42**	**24**	**80**
Pelletised poultry manure	**42**	**24**	**80**
Paper waste	**34**	**29**	**97**
Seaweed extract	**27**	**37**	**123**
Bovine manure composted	**19.6**	**51**	**170**
Pig litter (30%)	**14**	**71**	**237**
Green waste	**30**	**33**	**111**
Earthworm casts	**7.8**	**128**	**427**

In comparison, animal manures such as poultry manure, pig litter and bovine manure will contain high amounts of inorganic and organic minerals that increase the value of these fertilisers. No two products are the same and the plant and soil needs for all of the nutrients supplied is an important criteria that will determine the environmental impact of a fertiliser if nutrients are supplied in excess. The important factor here is the form in which N appears and the fate of this element after soil application. Clearly mineralisation and subsequent nitrification of organic-N will lead to nitrate availability for plant growth, but also any nitrate in excess to plant requirements will leach below the rooting zone and lead to acidification. On the other hand, a compost that is high in N may nitrify leading to volatilisation losses of N as ammonium, which will also be unavailable for plant growth.

ABC News

Opinion and Analysis

Opinions, essays, letters and comment on issues of national interest.

Digging into soil carbon warrants study

By NFF president David Crombie

Posted Tue Mar 31, 2009 9:21am AEDT
Updated Tue Mar 31, 2009 9:29am AEDT

Scientists worldwide recognise the very real opportunities for reducing greenhouse gas emissions in the atmosphere through storing carbon in biological systems.

How much carbon is agriculture absorbing? Nobody knows, and this is where Australia can truly lead the carbon debate. (ABC TV News - file image)

The Inter-Governmental Panel on Climate Change, Australia's own Garnaut Report on Climate Change and, indeed, the Australian Government have all confirmed carbon capture - including through soils, crops and pastures - is a reality.

One problem is realising the potential. How do we monitor, measure and evaluate the net emissions and/or storage of carbon across Australia's 155,000 farms?

Federal Agriculture Minister Tony Burke recently announced $32 million to study the role soil plays in storing greenhouse gases.

This biosequestration occurs naturally through the process of photosynthesis. Farmers facilitate photosynthesis as they plant crops, encourage pasture re-growth and sustainably manage vegetation to ensure their land continues to be productive. In fact, over 94 per cent of Australian farmers actively employ natural resource management practices as a matter of course.

However, the international carbon accounting rules, set by the United Nations Framework Convention on Climate Change, misguidedly focus on carbon emissions and fail to recognise biosequestration through agricultural or any other means.

This is not only short-sighted but, frankly, ignorant. If governments are serious about tackling carbon pollution, then they need to fully understand the total carbon cycle - how much is being emitted and how much is being sequestered. This then needs to be fully accounted for in any carbon trading regime.

Globally, agriculture makes up around 12 per cent of all emissions - in Australia, around 16 per cent. Even though Professor Garnaut and others have cited Australia as among the lowest emitting farm systems on Earth, while producing food and fibre for everyday human existence, we're told it's still too high.

But what of the other side of the ledger? How much carbon is agriculture absorbing? What is the 'net' carbon effect of this biological release and capture on the environment? Nobody knows, and this is where Australia can truly lead the carbon debate.

We've seen grossly misleading assertions by those with an ideological, sometimes zealot-like, position regarding agriculture's 'major' contribution to global warming. However, such claims come from a factual vacuum, ignoring carbon being removed from the atmosphere through farm practices.

In effect, when it comes to carbon and agriculture, the public is only getting half of the story.

While opportunities through biosequestration are real, there are variables. Different farms will have varying capacities to store carbon in their soil, depending on soil types, rainfall patterns and production systems.

Nevertheless, for those with the right preconditions, building soil carbon can have additional positive spin-offs through improving water retention capacity of soils and enhancing vegetation's ability to soak up nutrients.

That's why the National Farmers' Federation is calling for an 'opt in' approach, alongside the Government's Carbon Pollution Reduction Scheme (CPRS).

It is universally agreed agriculture cannot be covered by the proposed CPRS, and may never be. But there must be capacity for the sector to contribute to carbon reduction in a positive way.

Through research and development on soil carbon, we can explore human-induced sequestration opportunities throughout the complete biological system.

From what we already know, farmers can start designing appropriate, voluntary, market-based means that incentivise maximising soil carbon - and other forms of biosequestration - through complementary activities to the CPRS.

As new research findings and opportunities come to light, these activities can, and should, expand to reduce atmospheric carbon levels.

In fact, a new report by McKinsey and Company, Pathways to a Low Carbon Economy, not only notes the "very large" potential for carbon sequestration in soils, but goes further in saying it could be delivered "at a neutral cost or - net-profit-positive to society and require no substantial capital investment".

But, as I have alluded to, this is all academic without international carbon accounting rules changing to take stock of the full carbon cycle.

At present, the rules penalise countries who seek credit sequestering activities through soils, crops and pastures by making them liable for carbon from unforeseen and unavoidable natural disasters, such as droughts and bushfires.

Proactive countries, including Australia, are effectively shut-out from gaining carbon credits because of these unreasonable penalties.

We are encouraged by the Australian Government's commitment to reforming the rules, seeking to delink sequestration and natural disasters. Meanwhile, we should not be deterred from pursuing positive actions to increase soil carbon sequestration.

And, more pointedly, if the goal is to reduce carbon emissions, then regardless of accounting rules and trading schemes, shouldn't we be doing it anyway? If we're to be hamstrung from what we know works because of an accounting construct, then, I would suggest, the powers that be have missed the point.

For our part, Australian agriculture has a positive role to play. We need to be allowed to get on with the job of sequestering carbon through farm systems, while continuing to deliver food and fibre Australians - and the world - are increasingly relying on.

David Crombie is president of the National Farmers' Federation.

Tags: environment, climate-change, rural, australia

IGNITE ENERGY RESOURCES PTY LTD (IER)

- IER is a natural resource and eco-technology company based in Melbourne, Australia that is focussed on the development of the Gippsland Basin, Victoria brown coal (lignite) resource in Mineral Rights Licence EL 4416. This Licence area contains about 18 billion tonnes of relatively shallow measured, indicated and inferred lignite resources, with a potential 200 – 300 billion tonnes of deeper (currently unmineable) coal, making this one of the world's greatest undeveloped energy assets.

- IER is an integrated energy company capturing high margins by converting low value lignite into high value, clean liquid and upgraded coal energy products.

- IER owns unique thermal hydrolysis technology that is fundamentally different from other coal conversion technologies. IER uses water at near supercritical temperatures and pressures to selectively de-polymerise the lignite polymer and does not result in the wholesale destruction that is a feature to other coal-to-liquid technologies.

- This IER process emits only a fraction of the carbon dioxide when compared to alternative coal conversion technologies, is economically viable at much smaller scale and hence, has less capital cost of entry.

- IER has built a pilot plant at a facility north of Sydney, Australia and is producing, at small scale, high value oils, speciality chemicals and micronised coking coal and carbon products.

- IER has some 200 – 300 billion tonnes of deep seam lignite in EL 4416 and has demonstrated commercial grade coal bed methane in a 10-well pilot programme.

- IER plans to establish a bio-organic fertiliser industry based on the EL 4416 lignites. IER's partner in this project is Australia's leading biological farming systems company that has delivered successful, sustainable outcomes to farming enterprises across southern Australia.

- IER is in substantive discussions with potential partners for the development of a bulk coal processing and export industry based on the vast resources in EL 4416. IER welcomes approaches from energy companies interested in participating in this type of project.

- IER has initiated the process to apply for mining licences on both the Gelliondale and Stradbroke deposits. Applications for these licences are expected to be lodged in early 2009.

- IER is in advanced negotiations with coal owners in North America and Europe for the licencing/application of the IER supercritical coal conversion technology.

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BioLogic Farming Systems

The Best Practice in Agriculture

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LawrieCo has developed the most advanced and successful BioLogic Farming Systems (BFS) for Australian Agriculture.

The LawrieCo BFS delivers practical solutions to raise profits in farming, reduce chemical and synthetic fertiliser use and build soil chemical, biological and physical fertility (including carbon).

BFS is a proven performer that can significantly sequester atmospheric greenhouse gases like carbon dioxide back into your soil producing better farm outcomes as well as a greener environment for all.

Adopting BFS also leads to a significant reduction in the use of nitrogen fertilisers (between 30% and 100%). Over use of nitrogen fertiliser can contribute significantly to the emission of nitrous oxide, a potent greenhouse gas.

BioLogic Farming Systems are firmly based in the practical application and detailed understanding of Natural Sciences. All of LawrieCo's programs and products are based on sound scientific research and proven outcomes when implemented in the field.

LawrieCo Agronomic staff are fully qualified graduates and researchers in the fields of Agricultural Science, Soil Chemistry and Micro-Biology. Our company invests significant resources in a year long BFS induction and training program to ensure our BioLogic insight and consultation service to you is well advanced and second to none.

LawrieCo also employ research scientists who are expert in their fields to further develop and refine the programs and products required to ensure BFS has the best answers for Agriculture including Horticulture, Viticulture, Dairy, Pastoral, Tree Cropping, Mixed Farming, Animal Husbandry and Broad Acre.

BioLogic products and programs are often customised to meet the unique objectives of your farm. Every farm has different agronomic circumstances to work with and the BFS can meet those needs productively. Programs can also be tailored over various timelines to ensure the farm budget is carefully managed as well.

A distinguishing feature of BFS is that it provides effective programs to reduce environmental stress, disease and pests on your property.

History of LawrieCo

Established in 1998 LawrieCo has been built on a passion for improved farming techniques and commitment to working closely with farmers to enhance soil fertility and crop output with reduced chemical usage.

The concept developed when LawrieCo founder Adrian Lawrie began using (then little known) biological soil principles on his broad acre cropping property located in the marginal rainfall region between the Southern Flinders Ranges and upper Spencer Gulf region of South Australia.

Despite good yields, high inputs and use of conservation farming techniques (full stubble retention and limited cultivation) the soil was becoming more compacted, and soil organic carbon that started low, was getting lower. This trend was the catalyst for investigation of alternative farm practices and in 1996 Adrian planted 1200 hectares of crop with additional humates, soft rock phosphate and beneficial microbes brewed on site (three integral BFS inputs).

Following positive broad acre results, LawrieCo developed the BFS for large broad acre production, with success in overcoming soil compaction, building soil organic carbon, maintaining profitable yields and improving soil water holding capacity.

In 2009 over 250,000 hectares, in a wide variety of agricultural pursuits, are using the LawrieCo BioLogic Farming System.

The passion and the mission for LawrieCo BioLogic continues!

Australia's Soils Are In Trouble...

"Soil is alive with trillions of minute organisms that recycle nutrients and help plants grow.

Soil is the engine room of life. The sun provides the energy, the plants convert and store it and the soil organisms drive the whole system.

Australia's soils are in trouble. They are increasingly being poisoned with salt and chemicals. Many areas are compacted and eroded. Our soils are tired and over worked."

Source: Healthy Soils Australia

With seriously declined soil carbon and fertility indexes, most Australian agricultural soils are now severely challenged. The uptake of BioLogic Farming Systems by farmers lies in the ability of BFS to rebuild the soil fertility and farm profitability which have both declined.

BFS systematic approach to rebuilding the natural soil and plant interactions between soil organic carbon (humic and fulvic acid), micro-biology, mineral balance and trace elements is the key to recovering degraded soils economically and sustainably.

What is BioLogic?

BioLogic is a pursuit of agricultural practices that creates soil mineral balance, promotes organic soil carbon and increases healthy soil biota to ensure sustainably productive soils.

BioLogic combines agricultural input products into programs and a whole farming system to achieve these outcomes.

BioLogic On-Farm Programs

Broadcast

BioLogic Blend forms the basis of the soil broadcast program & is comprised of colloidal phosphate, agricultural basalt, organic humates, kelp, molasses, bacteria and fungi. Other minerals and trace elements can be included in a prescription blend made specifically for your soil.

It is a complete fertilizer & very effective soil conditioner with minerals chelated in a high carbon, organic base.

The humic acid released from the humates magnifies nutrient uptake and stabilizes minerals such as phosphorus and nitrogen prone to leaching or "lock-ups".

The microbial inoculants in LawrieCo BioLogic Blend make it a "living fertilizer" and ensures optimal plant nutrient uptake.

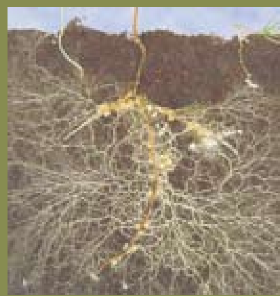
Seeding – Dry & Liquid

The BioLogic Seeding Program is designed to improve fertiliser efficiency and enhance crop or pasture development with high quality humic acid, balanced nutrition and beneficial biology.

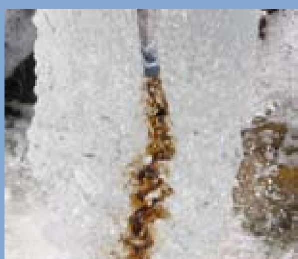
Combining reduced rates of fertiliser with BioLogic Soluble Humates Granules and SureCrop VAM seed dressing (includes VAM fungi) means the program is suitable for all crops and establishing pastures.

BioLogic Crop Start is a liquid fertiliser solution that combines the above elements (humic acid, VAM fungi and nutrition) in a one pass seeding treatment.

Tailor the program (dry or liquid) to your soils specific needs by adding trace elements.

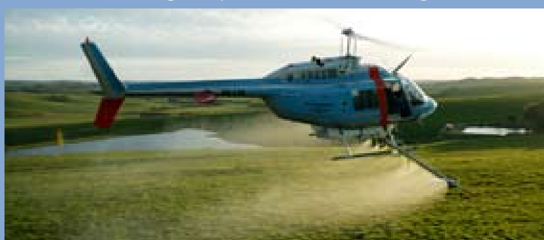


Foliar & Fertigation



Foliar or fertigation of nutrients and beneficial biology can give plants a needed boost. BioLogic liquids will stimulate root growth, raise plant energy levels and make nutritional inputs more effective. The benefits of adding biology include better nutrient uptake by plants, enhanced breakdown of organic matter, fixing free nitrogen and they provide a natural pest and disease protection mechanism.

Natural wetting and buffering agents also assist plant uptake of water by lowering surface tension, reducing water requirements and buffering the plant and soil from high salt, chlorine and minerals



Tissue analysis at this time is an important tool for management. Foliar or fertigation can then be used to make the necessary additions right when the plant needs it most.

Stubble & Residue Digestion

The digestion program breaks down plant residues, converting them into stable and useful forms of organic carbon, most importantly humus.

When applied to pasture or stubble the program converts the unpalatable plant matter into a nutritious feed source for stock.

The fungal species used in the digestion program are hardy, drought resistant and selected from Australian soils and are best suited to breaking down high cellulose brown residues and releasing locked up nutrients from dry plant matter.

Monitor the Soil to Manage Outcomes

A comprehensive soil audit provides important information about your soil. Current soil physical and analytical tests are required for a successful BioLogic recommendation to be made. Follow up testing is required periodically to ensure optimal results. You can Request an on farm visit and soil sample collection from a LawrieCo Field Consultant.

Animal Health Supplements

LawrieCo produce Humate based BioLogic Stock Licks and feed supplements like BioLogic VET and Kelp Support to ensure there are natural, biologic answers to maintaining animal health and welfare in a high production farming enterprise. Forage grown under a conventional systems is often high in non-protein nitrogen, low in complex carbohydrate energy and low in essential trace elements needed to ensure a healthy and nutritionally balanced diet.

LawrieCo supplements ensure that stock can improve rumen function, buffer the harmful effects of poor feed and provide the essential health requirements while necessary soil and pasture improvements for long term health and sustainability are underway.

Chemical Buffering

Using a biological adjuvant to buffer chemicals is important, every step you take toward reducing the negative effects on soil biology makes a difference.

LawrieCo Field Support

Our team of Field Consultants are trained to simplify the implementation of BioLogic Farming Systems on your farm.

Your assigned LawrieCo field consultant is trained to be a constant source of valuable information and should be considered as your personal BioLogic farming enterprise coach.

LawrieCo also organise and sponsor BioLogic Discussion Groups (BDG) in many regional areas for the purposes of networking with other BioLogical Farmers and gaining all the extra information and expertise required to make informed decisions about farm inputs and management. BDG's are a vital link between innovative and aspiring BioLogic farmers and success.

LawrieCo provide you with hands on guidance to measure, monitor, and manage your crop and pasture.

LawrieCo Locations

LawrieCo delivers successful BioLogic Farming Systems to clients throughout Australia, with most clients located in Southern and Eastern Australia with a recent expansion in Western Australia.

LawrieCo Field consultants are spread within these areas.

LawrieCo has multiple production and warehouse sites to deliver economical BFS programs to our clients.

LawrieCo Timboon Production Site in Victoria's South West will be the main location for production of high quality humic and fulvic acids by the end of 2009.

LawrieCo management and administration occurs in the Head Office located at Wingfield, South Australia.

Year on Year BioLogic Farming Systems **Keep Producing Results**

Cropping
Eyre Peninsula SA
Bill Butterfield
2008: With 170mm rainfall to October BFS wheat paddocks averaged over 2 T/Ha, while harvest average for other wheat paddocks was 1.4 T/Ha

Dairy, Cooriemungle Vic
Darryn Smith
"The results I saw after the first two months matched the outcomes that I thought would take three or four years. It is understandable people find it hard to believe what they are seeing."

Mixed Farming, Mingay Vic
Brian Wilson
"Where more blend (BFS) has been applied, infiltration rates have increased, mineral availability and balance have improved, and insect damage and pathogenic disease have decreased."

LawrieCo

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