Building Soil Organic Carbon using Biological Farming Systems in Australia's more Intensive Agricultural Regions

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 agricultural productivity and the environment.

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.

Building Soil Organic Carbon (SOC) requires two things: green plants and soil microbes.

Soil microbes: The lost link in current intensive chemical agricultural practices

"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

APPLICATION OF BFS IN AGRICULTURE

BFS restores the microbial, chemical and physical health of the soil. This increases plant nutritional balance and integrity and the natural recycling process resulting in more carbon being sequestered. Improving soil health and plant nutrition integrity elevates plants' natural resistance to environmental impacts, including drought, frost, disease and insect effects.

BFS can be implemented on a large scale using biological fertiliser inputs and methods that promote soil biota. A key inclusion in this system is humus, currently derived from Victorian lignite (brown coal) and blended with solid and liquid plant nutrients and other biological stimulants.

BFS is used by over 300 farmers on over 300,000 hectares in Australia. Below are the benefits these farms are gaining.

1. Reduced chemical fertiliser use, including:
    - Nitrogenous fertiliser, reducing relative Nitrous Oxide (GHG) emissions
    - Chemically treated phosphate fertiliser
2. Reduced incidence of pest and disease and subsequent use of insecticide/fungicide sprays
3. SOC increases of 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/reduced water use
7. Better soil fertility index – mineral balance, biological activity and physical structure (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

Scope for BFS in Australia

Economical and practical implementation of BFS are viable in more intensive agricultural production regions. Currently BFS are used in a variety of production systems across low, medium and high rainfalls; primarily broad acre cropping, pasture, dairy, viticulture and horticulture – over 300 Australian farmers covering over 300,000 hectares.

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). Australia's cropped area is 24.7M hectares which includes dry land and irrigated production.

Building SOC from Atmospheric Carbon Dioxide

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

The final process, humification, stabilises organic carbon additions to soil so that the carbon gained from plant roots does not recycle back to the atmosphere as carbon dioxide. The process involves soil microbes to transform the carbon additions into stable humic substances which are long term stores of SOC (from decades to centuries).

Carbon additions from plant growth need to be combined with land management practices such as BFS that promote soil microbes and the conversion of transient forms of SOC to stable complexes within the soil.

BFS outcomes that promote soil microbial activity and subsequent stable SOC additions:

1. Minimise chemical use, buffer when appropriate
2. Reduce chemical fertiliser use and stabilise with a carbon source (humus based substances)
3. Maintain ground cover (residue retention and digestion)
4. Increase plant root growth (root exudates also feed soil microbes)
5. Condition soil with humus based inputs, primarily derived from lignite brown coal
6. Minimise soil disturbance through tillage
7. Avoid burning crop residues

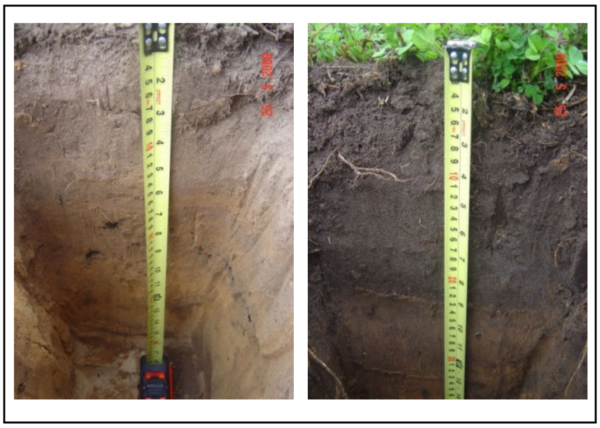

Image 1. Low carbon soil *Image 2. High carbon soil*

Soil which has a high SOC percentage is visibly darker in colour, which is partly due to the humus content of SOC. The soil in Image 2 (above) has used BFS for 12 years.

BFS CO_2 Sequestration Estimate

The estimate in Table 1 below uses Australia's cropped area of 24.7M hectares which is dry land and irrigated area, which is a relatively small component of what could be achieved across the more intensive agricultural production area in Australia (167M hectares). Greenhouse gas emissions in cropping production are currently high and increasing because of chemical fertiliser, pesticides/fungicides and diesel use as traditional solutions to production problems.

Table 1 below illustrates the significant quantity of atmospheric CO_2 that can be sequestered per annum by a given area adopting BFS with an absolute SOC increase of 0.15%. This increase is conservative and realistically achievable by adopting BFS. BFS field results have shown SOC to increase by 1.2% over 3 years in samples taken from the top 15cm of soil.

Table 1. ***Quantity of CO_2 sequestered (tonnes) by a total SOC increase of 0.15%, to 0-15cm soil depth and bulk density 1.5g/cm^3 over an area (Ha) in one year.***

Agricultural area treated with BFS (Ha)	As a % of the cropped Area in Australia (24.7M Ha)	Equivalent CO_2 sequestered per annum (tonnes)	% of Australian annual CO_2 emissions	Value of carbon credits
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

***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. SOC increase is a conservative 0.15% per annum. BFS field results have shown SOC to increase by 0.4% pa 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.

The conservative estimate is that 25% of Australia's annual CO_2 emissions can be sequestered by 50% of Australia's cropping area adopting BFS and subsequently increasing SOC.

OTHER CONTRIBUTIONS FROM BFS IN ADDRESSING CLIMATE CHANGE

Farmers using BFS make significant reductions in the quantity of chemical fertiliser used in the production system; with the added benefit of reducing potential emissions of Nitrous Oxide. Changes in the use of inorganic nitrogen fertiliser range on BFS farms from reductions of 30% and up to 100% of previous use.

GRDC Research Updates report Nitrous oxide (N_2O) is a greenhouse gas that can be emitted from agricultural soils and is of particular concern as it has 310 times more global warming potential than carbon dioxide 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 nitrogen 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 water logging. (Nitrous oxide emissions from cropping systems - GRDC Research Updates)

Table 2. An example from 400 hectare broad acre cropping property in the Mid North of South Australia, reducing nitrogen inputs by 86%, with potential reductions of 58.8T CO_2 equivalent per annum over the property.

Fertiliser Use Compared	**Phosphorus** Units or kg	**Nitrogen** Units or kg	**N_2O Emissions** (kg) Over 400 Ha	**CO_2 Equivalent** (kg) Over 400 Ha
80-100kg/H1 DAP 60kg/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**

SUMMARY POINTS

- ✓ Building soil organic carbon on half of Australia's cropping regions (12.3M hectares) has the potential to sequester over 150M tonnes of CO_2 (one quarter of Australia's annual CO_2 emissions) each year through the adoption of Biological Farming Systems.
- ✓ Potential for CO_2 sequestration from 167M hectares of more intensive agricultural production in Australia using BFS to build SOC is over 2 billion tonnes annually.
- ✓ Lowering emissions of nitrous oxide from reduced inorganic fertiliser use with BFS
- ✓ BFS results in a carbon neutral application of lignite brown coal