Filling the Research Gap – Round 1

National Soil Carbon Program

NSCP Co-ordinating team: Ram Dalal, Jodie Frommolt
NSCP Aims

- Lead and provide high level coordination through national research network of soil carbon projects
- Develop and deliver most effective and practical strategies for managing soil carbon
  - Increasing and / or reducing the loss of soil carbon
  - Improved modelling capability
- Findings of the Program are synthesized under four themes:
  - Improved measurements to reduce uncertainty and costs
  - Vegetation management
  - Management practices
  - Organic amendments
- Future Research Needs
Measurements to reduce uncertainty and costs in soil carbon stock estimates: Summary of Key Facts

- **Improved soil sampling designs** for large spatially variable landscapes

- Sampling each time within a season and calculate SOC on ESM basis to **reduce uncertainty** in SOC estimates. Standard deviation of ±3.3 t/ha in top 30 cm over a 2-year period observed

- Monitoring of SOC stock changes over years must **account for rainfall, soil type and land use** effects as well as calculated on an ESM basis

- **On-the-go NIR** field estimates of SOC stocks with further improvements will be a **cost-effective** technique

- **SOC modelling** such as in FullCAM

Andrea Ramirez Sepulveda performing total carbon analyses using a LECO TruMac analyser – Courtesy Jeff Baldock
Measurements - Emissions Reduction Fund methodologies

- Provided sampling procedures for the CFI-ERF methodology ‘Carbon sequestration in soil in grazing systems’


Courtesy: Jon Sanderman
Vegetation management – Regrowth, environmental plantings, reforestation and perennial forage plants: Summary of key facts

- SOC stocks (0-0.3 m depth) ranged between 17 and 79 t/ha and varied with land use in the order: Remnant> Regrowth> Pasture

- Total C sequestration 15 years after plantings varied between 2.2 and 10.0 t C/ha per year. On average, 66%, 26% and 8% of this sequestered C was in the biomass, debris and soil pools, respectively (SOC seq range: 0.18 – 0.8 t/ha per year)

- SOC stocks increased by 0.55±0.13 t/ha per year on previously cropped lands, but only 0.24±0.09 t/ha per year on previously grazed lands.

- Reforestation of pasture land restored C loss of 59 t/ha, a C gain of 8.4 t/ha per year, mostly in the above-ground biomass and tree roots

- Perennial forage plant, *tagasaste ungrazed* contributed 2.5 t C/ha per year over 22 years, an increase of 1.31 t/ha per year, mostly in the top 10 cm depth
Vegetation management - Reducing greenhouse emissions

- LUC from crop and pasture lands to reforestation, SOC sequestration rates 0 - 1.3 t C/ha per year, and including the above-ground biomass increases it up to 10 t C/ha per year.

Project Leader Tim Smith (DAFF, QLD) soil carbon sampling in a spotted gum (Corymbia citriodora sbsp. variegata) plantation and adjoining pasture at Binjour, QLD.
Vegetation management - Emissions Reduction Fund methodologies

- CFI Reforestation Modelling Tool (RMT) extension into a single ERF method, ‘Modular Forest Sequestration Method’, including soil C stocks in this FullCAM-based method

- The dataset from the NSCP projects on vegetation management will be useful for this enhancement of the ‘Modular Forest Sequestration’ method

Courtesy: Tim Smith
Vegetation management - Increasing productivity

- Facilitated forest regrowth – leguminous trees restore fertility, grazing

- **Perennial forage plantings** – grazing, fertility restoration and reduce salinity and erosion

- Reforestation - **Restores degraded lands**

- Environmental plantings – plus **shelter belts** – shade and wind breaks **agriculture production**
Vegetation management - Sustainable land use

- **landscape remediation**, e.g., riparian plantings to improve water quality, plantings in saline or waterlogged landscapes, reduce erosion
- **reforestation of degraded lands**, 
- tagasaste plantings to **reduce salinity** downslopes, 
- land use sustainability by **decreasing wind and water erosion** and by **improving** soil physical, chemical and biological functions – **soil fertility**

Management practices – Croplands and grazing rangelands: Summary of key facts

- Small SOC increases from <0.1 t/ha per year to 0.3 t/ha per year. May take decades to be detected against background SOC stocks.

- For sandy soils, increasing amounts of clay was associated with increasing SOC stocks.

- Converting marginal cropping lands to permanent pasture increased SOC stocks by 0.1 -0.2 t/ha per year over 20 years depending on the cropping history.

- Improved pastures that include legumes and P application had higher SOC stocks (104 t/ha) than unimproved pastures (88 t/ha) due to improved N fertility.

- Management practices such as crop residue retention, green trash burning, and no-till have negligible effects on SOC stocks.

- A priming effect is implicated when fresh plant residues are added, that is, native SOC loss is accelerated, generally no net change in SOC stocks may be observed.
Management practices – Croplands and grazing rangelands: Summary of key facts

- **APSIM simulation** of 3 long-term trials in eastern Australia for SOC stock changes had uncertainty of <10% or between 2.9 t/ha and 6 t/ha of actual SOC stocks (0-0.3 m depth)

- **High stocking rates reduced SOC stocks by >10%** in southern Queensland and northern NSW, ≤5% in southern NSW, but not in Victoria (APSIM)

- Reducing the **total grazing pressure** (excluding non-stock animals) had SOC stock 8.7 t/ha higher than total grazing pressure for some soils (Kandosols)

- SOC stocks in the top 0.1 m increased by **0.7 t/ha for every 10% increase in ground cover**, may be partly due to a reduction in the SOC loss by erosion.
Management practices - Reducing greenhouse emissions

- Conversion of land use from cropping to pasture increases SOC stocks by as much as \(0.2\) t C/ha per year; higher in improved pastures with fertiliser inputs and / or introduced legumes

- Over a number of years at relatively high rates, C inputs increase SOC, at least temporarily

- At lower rates, \textbf{SOC increase from residue retention is insignificant}, including that from green cane trash retention

- \textbf{SOC sequestration from no-till practice is insignificant}; however, no-till may reduce SOC loss rates from cropped soils, also noted in the previous SCaRP projects

- \textbf{Fertiliser} applications may \textit{increase SOC by conserving applied C}

- \textbf{Fertiliser N} application and C inputs \textit{increase} the emission of \textit{nitrous oxide} and this must also be considered along with SOC changes
Management practices - Emissions Reduction Fund methodologies

- Development of the methodology on ‘Carbon Credits (Carbon Farming Initiative—Sequestration of Carbon in Soil Using Default Values) Methodology Determination 2015’ in relation to crop to pasture no-till, residue retention and fertiliser applications.

- Potential methodology for rangelands that takes into account the total grazing pressure (both stock and non-stock animals) rather than domestic livestock only - ground cover.

- Improved SOC modelling from C inputs including ‘priming effects’.

Courtesy: Cathy Waters
Management practices - Increasing productivity

- LUC from cropping to pasture, especially on marginal lands improves the long-term productivity from land but requires economic analysis due to change in market prices.

- N management must increase NUE but decrease nitrous oxide emissions, besides increasing and stabilising SOC. These goals also lead to an increase in productivity.

Growth chamber used to grow isotopically labelled plant material which is used for field experiments – Courtesy: Clemens Scheer
Management practices - Sustainable land use

- LUC from **cropping to pasture** restores marginal and degraded lands

- Retention of crop residues and plant matter provides **ground cover**, which is essential to reduce soil erosion and SOC loss by **water or wind erosion**

- Even if SOC may not increase from **plant residue retention** practice it reduces soil erosion and therefore **reduces soil and SOC loss**

Courtesy: Fiona Robertson
Organic amendments: Summary of key facts

- MIR and NIR provides a rapid and economical tool to differentiate organic amendments, manures, composts, biosolids and biochars for their potential C sequestration and / or plant nutrient supply

- Biochar applied at 10 t/ha may sequester 5.4 t C/ha, but compost (25 t/ha) only 0.04 t C/ha, combined compost and biochar (COMBI, 25 t/ha), 1.4 t C/ha

- Crop yield responses up to 25% (sugarcane, peanut, maize) on Ferrosols on Atherton Tablelands and sandy coastal soils in north Queensland

Manual cane harvesting and weighing of sugarcane near Mourilyan in North Qld – Courtesy: Michael Bird
Organic amendments - Reducing greenhouse emissions

- **Biochar** increase SOC sequestration significantly but **manures** and **composts** marginally.

- **\(\text{N}_2\text{O}\) emissions reduced from biochar** application but **not from compost** or N fertilisers.
Organic amendments - Emissions Reduction Fund methodologies

- Rapid assessment of various organic amendments by **MIR and NIR spectroscopy provides datasets for FullCAM**, with plans to develop it into an ERF methodology for carbon offsets.

- **Unique dataset from north Queensland for an ERF Methods Determination** on organic amendments.

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Organic amendment ready to be incorporated into WA Tenosol for an 18 month incubation – Courtesy: Mark Farrell
Organic amendments - Increasing productivity

- Combined compost and biochar (25 t/ha) (COMBI) **increased crop yields by up to 25%** in sugarcane, maize and peanut on Ferrosols and sandy coastal soils in N Qld.

- **Increase water retention and CEC** of sandy and low-activity clay soils.

- Requires **economic analysis of biochar use**.
Organic amendments - Sustainable land use

- Organic amendments **increase SOC stock**. Many amendments such as composts and manures are all good sources of **plant nutrients**

- Application of organic amendments ensures reduced fertiliser use, sustainable land use and **increased productivity**

- A major limitation is the **availability, and transportation and application costs** of these amendments

Field Sites – Courtesy: Michael Bird
Future Research Needs

1. A statistical and scientific basis needs to be developed for identifying paired –sites, very useful for substituting the ‘time’ for ‘space’ factor in lieu of long-term experiments.

2. Uncertainty analysis needs to be undertaken for policy makers in a format that can easily be understood by end users.

3. Spatial-explicit information is required for project-based carbon activities related to ERF soil carbon methodology, and rates of carbon inputs for FullCAM-RothC model.

4. Further research is required for developing best management practice for balancing carbon sequestration, or avoided carbon loss benefits, with plant and animal productivity.

5. Reforestation provides one of the largest opportunities to sequester SOC, but further work is required to quantify additional benefits farm-integrated plantation.

6. Quantify the economic and environmental benefits from stabilising SOC stocks:
   - decreased erosion losses from establishment of riparian plantings and reforestation
   - restoration of degraded and highly eroded landscapes
   - improving agricultural productivity - fertility, soil structure, WHC, CEC, shelter belts
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