Soil organic carbon in Wheatbelt cropping systems

By Jo Wheeler

Why manage soil organic carbon?

Soil organic carbon is important for:

- **Cation Exchange Capacity (CEC):**
  CEC indicates the potential capacity of soil to store nutrients. The three main cations essential for plant growth are potassium, calcium and magnesium. These influence soil structure, colour and aggregate stability.
- **soil structure:**
  soil organic carbon interacts with and influences the formation of soil structure, helping the formation of soil aggregates.
- **water holding capacity in soils:**
  carbon acts like a sponge for soil water... more carbon = more plant available water holding capacity. Although these increases may be small, they may be valuable in below average rainfall years.

What are the forms for soil organic carbon?

Types of soil organic carbon and their role in agricultural soils:

- **crop residues:**
  above and below ground plant residues (leaves, stalks, roots) less than 2 mm long or wide
  - break down quickly
  - source of energy for soil biological processes
- **particulate organic carbon**:
  plant residues that are smaller than 2 mm but larger than 0.053 mm
  - breaks down relatively quickly but more slowly than crop residues
  - important for soil structure
  - source of energy for biological processes source of nutrients
- **humus decomposed materials**:
  less than 0.053 mm that are dominated by molecules stuck to soil minerals
  - important for all key soil functions
  - provides nutrients - for example the majority of available soil nitrogen derived from soil organic matter comes from the humus fraction
- **recalcitrant organic carbon**:
  biologically stable carbon, most common form is charcoal
  - decomposes very slowly and is therefore unavailable for use by micro-organisms
  - carbon that will not be readily-emitted to the atmosphere as CO_2

> **"more carbon = more plant available water holding capacity."**

How can we sequester soil organic carbon?

Plant photosynthesis is the only process by which carbon is taken from the atmosphere and a fraction deposited in the soil through inputs of plant organic matter.

- Soil organic carbon input rates are determined by the root biomass of a plant, but also include stubble and leaf litter deposited from above-ground plant material.
- Practices that improve plant water use and growth (e.g. early sowing) are desirable because they also increase organic inputs into soil.

The capacity of a soil to store soil carbon over a long period of time is largely determined by the characteristics of that soil and climatic factors (this is referred to as 'attainable' soil carbon). Soils that have more clay content and occur in higher rainfall environments have been found to be able to store more carbon, while sandier soils in drier environments tend to be lower in soil carbon. Increasing the rate of organic inputs on coarse sandy soils may therefore not result in stable increases in soil organic carbon but may help to maintain the current soil carbon stock.

Soil management activities can be used to move soil carbon stocks towards their attainable levels. For example, in the Avon Arc region, maximum attainable carbon levels in cropping systems on sandy soils have been estimated to be approximately 40t-C/ha, while studies have measured an average actual carbon level of 19t-C/ha in this area.

Limiting gaseous emissions (respiration) of carbon from soils is a sequestration process. There are a number of ways to do this, the easiest to achieve are below:

- Limit soil disturbance to ensure the carbon protected from decomposition by soil microbes by clay or soil aggregates continues to be protected.
- Increase plant cover to ensure there is an input of carbon to the soil from root and above-ground biomass. Soil left fallow is a net source of carbon to the atmosphere because there is no addition of carbon to counterbalance the loss of carbon from erosion or microbial respiration

Respiration rates are highest when conditions are warm and moist, meaning that summer rainfall can cause the rapid release of soil carbon, particularly if there are no active plants to replace the lost carbon. A recent Wheatbelt study by UWA suggested that soil organic carbon levels had, on average, dropped.

Nutrient Use Efficiency

By Dr Guy Boggs

> **"Inefficient use of farm nutrients is causing lost profitability and poor river health."**

Nutrient use efficiency is becoming increasing important as the cost of fertilisers continue to rise. Additional, Swan-Avon River Catchment modelling has identified the importance of addressing nutrient management on farms for healthy waterways

An integrated approach to nutrient management supports landholders through soil analysis, development of nutrient management plans and better practices, improving crop performance through soil health while reducing nutrient export to waterways. This is a joint initiative between Perth NRM, Wheatbelt NRM and the Department of Parks and Wildlife.

The Nutrient Management Use Effieciency program is to developing soil monitoring, management and nutrient planning demonstration sites across the Avon River Basin which will then be used to develop a series of extension activities and materials to encourage neighbouring farmers to prioritise soil health and nutrient management.

This extension will build an understanding of the soil health factors limiting production amongst the farming community (Soil pH, compaction, salinity, toxicity, pests and diseases), and provide training in the use of decision support tools and technological advances that will enable farmers to manage nutrients better and to independently interpret soil testing results to guide soil management.

Farm nutrient-use inefficiencies are caused by:

The major cause of nutrient pollution in the Avon Basin is the inefficient use of farm nutrients*. Farm nutrient-use inefficiencies are caused by:

- Drought
- Livestock (animal farming is inherently less nutrient efficient than cropping)
- Excessive nutrient applications relative to seasonal fertiliser requirement
- Soil acidity
- Poor timing of nutrient application and the loss of nutrients during intense weather events
- Poor soil structure
- Low soil biological activity.

The Nutrient Use Efficency project process:

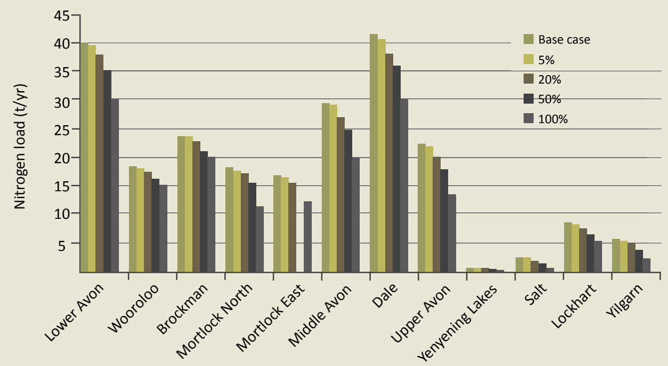
Paddock analysis and planning	Soils sampled to depth	Crop tissue testing	Final assessment
Paddocks will be mapped into zones using available data, growers knowledge and paddock visual assessment	Sample results compared using industry standards for critical values and mapped using traffic lighting	Tissue testing will be utilised to assess limiting factors to the crop	Nutrient balance is used to determine the efficiency of the fertiliser budget

The table below explores the nutrient inputs and outputs for an average Wheatbelt wheat & sheep and mixed grazing farm based on current farming practices ('base case'), liming to address soil acidity and implementing on farm nutrient management. The table demonstrates that nutrient use efficiency (NUE) for nitrogen currently sits at about 41% and phosphorous at 48% in wheat & sheep farming. However, this can be improved to 48% (nitrogen) and 56% (phosphorous) by addressing soil acidity, or 56% (nitrogen) and 75% (phosphorous) through the adoption of relatively simple nutrient management practices. This equates to an average of almost 15 kg/ha/yr of nitrogen and 2.6 kg/ha/yr of phosphorous not being 'wasted' (surplus) on farm simply by liming and incorporating nutrient management practices such as soil testing for nutrient sufficiency to depth, plant tissue testing and better timing of fertiliser application. If all farmers in the Avon Basin were to adopt these improved nutrient management practices, the modelling suggests nitrogen loads would decrease by 153 t/yr and phosphorous loads by 2.4 t/yr at the catchment outlet, with the Mortlock, Dale and Middle/Upper Avon catchments providing the greatest decrease in nutrient out flows.

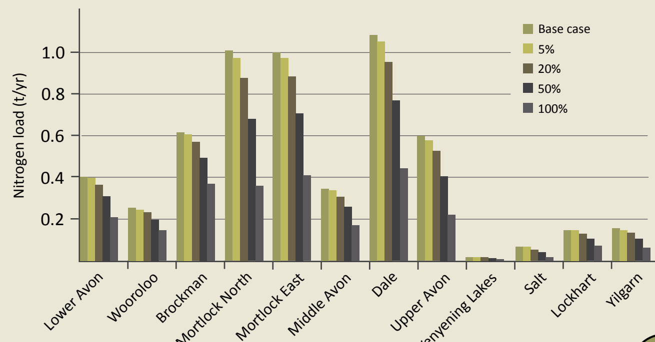
Average annual nitrogen loads for the modelling catchments for the farm nutrient management scenarios*

Scenario	Nitrogen				Phosphorus			
	Input (kg/ha/yr)	Output (kg/ha/yr)	Surplus (kg/ha/yr)	NUE (%)	Input (kg/ha/yr)	Output (kg/ha/yr)	Surplus (kg/ha/yr)	NUE (%)
Wheat & sheep								
Base case	60.7	25.0	35.7	41	7.7	3.7	4.0	48
Soil acidity management								
Liming	60.7	29.3	31.4	48	7.7	4.3	3.3	56
% difference			-12	17			-16	17
Farm nutrient management								
Efficient nutrient use	48.8	29.3	19.5	60	5.4	4.3	1.1	80
Drought year	48.8	9.8	39.0	20	5.4	1.4	4.0	27
10 year average	48.8	27.3	21.5	56	5.4	4.0	1.4	75
%difference			-40	36			-65	55
Mixed Grazing								
Base case	79.6	18.2	61.4	23	7.8	2.8	5.0	36
Soil acidity management								
Liming	79.6	21.3	58.3	27	7.8	3.2	4.5	42%
%difference								
No action	79.6	17.3	62.3	22	7.8	2.6	5.1	34
% difference								
Farm nutrient management								
Efficient nutrient use	70.9	21.3	49.7	30	5.4	3.2	2.2	60
Drought year	70.9	7.1	63.8	10	5.4	1.1	4.3	20
10 year average	70.9	19.9	51.1	28	5.4	3.0	2.4	56
% difference			-17	22			-52	57

Average annual nitrogen reporting catchment loads for the farm nutrient management scenarios*



Average annual phorphorus reporting catchment loads for the farm nutrient management scenarios*



*This article and the associated tables and graphs are based on information from: Hennig, K & Kelsey, P 2015, Avon Basin hydrological and nutrient modelling, Water Science Technical Series, report no. 74, Water Science Branch, Department of Water, Perth, Western Australia.