soil carbon, erosion + moisture conservation

in stubble retained systems in Central West NSW

Project code CWF00018

KEY MESSAGES

- Soil carbon and microbial health are positively correlated.
- Carbon is influenced by soil type, climate, length of the pasture phase, cropping intensity and management.
- Soil fertility depends on three interacting components: biological, chemical and physical.
- Retained stubble systems reduce all types of soil erosion and protect physical characteristics in the top layer of soil, compared to traditional cultivation systems.
- Reducing the rate of surface evaporation with stubble ground cover is not always possible especially if rainfall is low and evaporation demand high.
- When looking to conserve moisture in Central West NSW, understanding the main drivers behind fallow efficiency, including amount, frequency and intensity of rainfall, evaporative demand, the presence of weeds and stubble load, is essential.

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Soil moisture

Plant available water (PAW) at sowing depends on many variables including soil type, in-fallow rainfall, water infiltration rates, evaporation, transpiration from weeds, stubble load, drainage and in some cases, lateral flow.

Fallow management strategies including stubble retention and weed control can affect the PAW.

Over summer evapotranspiration often dries the soil surface (top 30cm) to the extent that the PAW is below the crop lower limit. Weed control and stubble retention can slow this process and may result in a greater amount of stored soil water. The amount of stored soil water before drainage occurs to the next soil layer is impacted by the particle size of the soil. Smaller soil particles are able to provide a stronger force on retaining water than larger soil particles.

Consequently clay based soils (smaller soil particle size) usually have a greater PAW than sandy soils. Some clay soils can hold as much as 42 mm between air pores before they reach the drained upper limit (Figure 1).

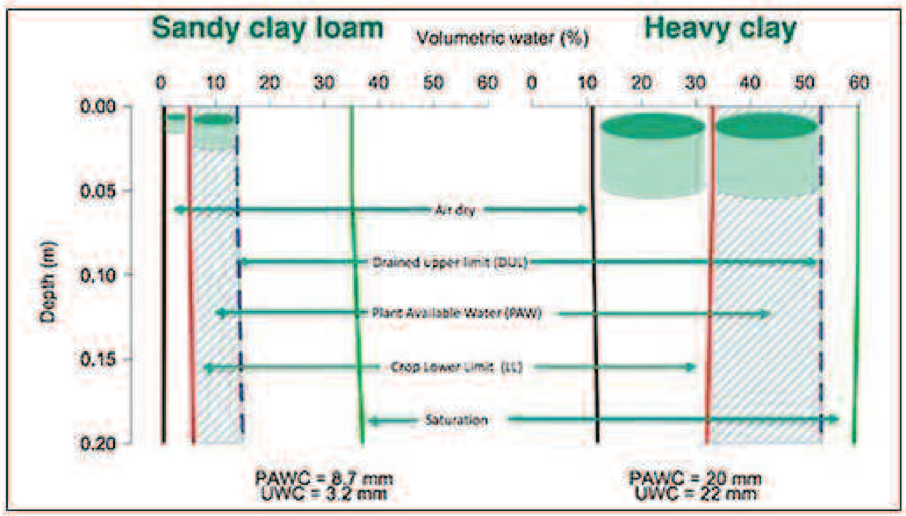

Figure 1: Diagrammatic representation of various soil water descriptions in two contrasting soil types to a depth of 20cm. Note the drained upper limit is often referred to as field capacity while the crop lower limit is often referred to as permanent wilting point. The sandy soil can hold 11.9mm of water between the air-dry value and the drained upper limit (8.7 + 3.2 = 11.9mm), although only 8.7mm is available to the plant as 3.2mm is unable to be extracted from the soil by plant roots. Source: http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Drivers-of-fallow-efficiency

Impact of rainfall patterns

PAW coming out of fallow is largely dependent on the depth of water infiltration and its exposure to evapotranspiration. The transpiration component can be managed by controlling weeds while the evaporation component can be influenced by stubble retention. Other events that cannot be controlled include the amount and intensity of rainfall, with a high amount and low intensity maximising the depth of water infiltration. Low amounts of rainfall are usually subject to greater evaporation losses as infiltration depth is usually insignifigant.

The timing of these events is also important as rainfall events closer to sowing reduce the time period under which high evaporation demand occurs.

Downward soil water movement is slow below field capacity and faster above field capacity and this helps explain why several rainfall events occurring close together facilitate the movement of water deeper within the soil profile. The rate of the soil water movement can also be impacted by the amount of stubble cover, the soil type and evaporative demand.

In low rainfall environments, relatively small increase in stored soil water may result in significant grain yield increases; however this research and that of Incerti et al. (1993) found water storage influenced by stubble retention has little or no benefit in crop yield, primarily because of high evaporative loads over significant time periods with little follow up rainfall. However, Cantero-Martinez (1995) found where soils had higher clay content and rainfall was more frequent, stubble retention did have a more consistent positive impact on PAW and grain yield increases.

Soil carbon

Soil carbon, or soil organic carbon (SOC), is the carbon stored within soil. Soil organic matter (SOM) 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 SOM until they start to decompose.

CSIRO scientists (Dr Jeff Baldock, CSIRO Land and Water and his team) have identified four biologically significant types or fractions of SOC that include: crop residues, particulate organic carbon, humus and recalcitrant organic carbon.

- **Crop residues** - shoot and root residues greater than 2 mm found in the soil and on the soil surface. Readily broken down and provides energy to soil biological processes.
- **Particulate organic carbon** – individual pieces of plant debris that are smaller than 2 mm, but larger than 0.053 mm. Broken down relatively quickly but more slowly than crop residues. Important for soil structure, energy for biological processes and provision of nutrients.
- **Humus** – decomposed materials less than 0.053 mm that are dominated by molecules stuck to soil minerals. Plays a role in all key soil functions. 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.
- **Recalcitrant organic carbon** – this is biologically stable; typically in the form of charcoal, a product of burning carbon-rich materials. Decomposes very slowly and is therefore unavailable for use by micro-organisms. Many Australian soils have high levels of charcoal from burning over many years.

Soil carbon in stubble retained systems

A long-term farming system trial at Condobolin as part of the Lachlan Soil Carbon Project (commencing in 1998 and completed in 2016) examined the impacts of various farming systems on soil properties. Soil samples were collected in 1999, 2004, 2008 and 2012 and used to determine the change in chemical properties over that time.

The project was managed by Dr Warwick Badgery and Kim Broadfoot (NSW DPI) with assistance from James Mwanda and Dr Neil Fettell of CWFS.

The different farming systems tested were (Table 1):

- Conventional tillage (CT).
- Reduced tillage (RT).
- Zero till continuous cropping (CC).
- Perennial pasture (PP)

A significant difference was found between several soil properties, but this largely occurred within the reduced and conventional tillage treatments that had a combination of both crops and pastures.

Table 1: The farming systems and cropping phases implemented at the Condobolin comparison trial. ***u/s: undersown with pasture; aP: after pulse***

Farming system	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
CT	LFW	SFW u/s	Pasture	Pasture	Pasture
RT	LFW	No crop	LFW u/s	Pasture	Pasture
CC	Wheat	Barley	Pulse	SFW aP	Green manure
PP	Pasture	Pasture	Pasture	Pasture	Pasture

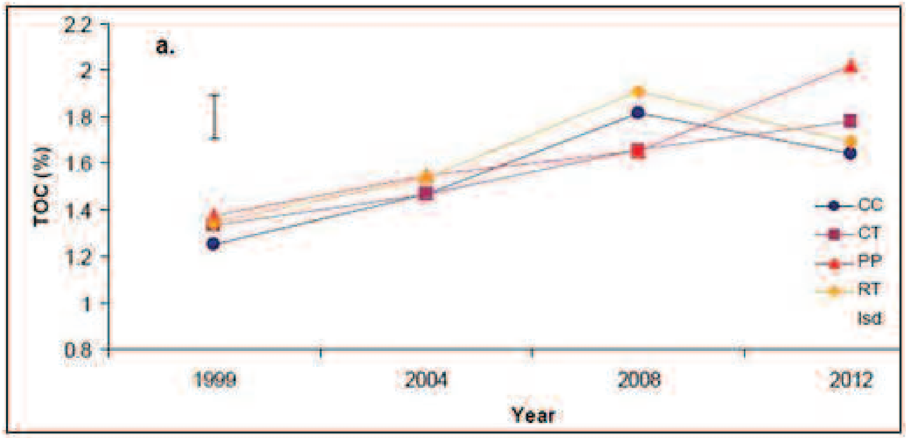

Figure 2: Total Organic Carbon (%) levels in the 0-10 cm soil profile measured during the experimental period. Standard error (mean) bars presented.

Table 2

Texture	No. sites	0-10^{o}C %	0-30cm SOC (t/ha)*
Sandy loam	3	1.15	26.2
Fine sandy loam	22	1.70	34.7
Fine sandy clay loam	17	1.90	39.8
Silty clay loam	3	1.97	41.0

These changes largely reflected the nutrient cycling dynamics of the two systems, e.g. fertiliser additions in the cropping phases (Figure 2).

The error bar in Figure 1 indicates that there is only a minimal difference between the various systems when it comes to storing soil carbon. The results could possibly be explained by the low levels of microbial activity in low rainfall environments.

Some key findings of the project

- Cropping paddocks have lower SOC than pasture paddocks.
- Higher P fertiliser applications resulted in higher SOC.
- Higher N fertiliser applications resulted in lower SOC.
- Tillage systems and stubble management had little influence on SOC; however this may be due to improved farming practices with less tillage than in decades preceding the project.
- Pastures with larger areas of bare ground have low SOC compared to pastures with good ground cover.
- Soil texture can significantly influence the amount of SOC e.g. clay loams storing almost double that of sandy loams (Table 2).

View the 'Changes in soil chemical properties under contrasting farming systems for a long-term experiment in the dry cropping zone' paper here, or follow link:

http://cwfs.org.au/wpcontent/uploads/2016/06/CWFS-soil-fertility-report-final_submitted-1.pdf

Factors that influence soil carbon

Soil carbon inputs:

SOC inputs are controlled by the type and amount of plant and animal matter being added to the soil. Any practice that enhances productivity and the return of plant residues (shoots and roots) to the soil opens the input tap, adding to the amount of carbon in the soil.

The majority of carbon enters the soil as plant residues.

Fire can also contribute by converting plant dry matter into charcoal which enters the recalcitrant fraction. However, fire itself can lead to carbon losses through the release of carbon dioxide.

A variety of management practices can increase soil carbon levels by increasing inputs. In theory, maximising productivity also maximises returns of organic residues to the soil. Practices that increase productivity may include fertiliser application, crop rotations, improved varieties, irrigation and crop intensification.

Reduced tillage or no-tillage management practices can also increase soil carbon levels as carbon in the crop stubble returns to the soil. In most systems no till or reduced till reduces the decline in SOC or maintains it at a constant level. Cultivation-based systems reduce SOC under current cropping practices.

Soil carbon can also be topped-up by direct application of organic materials to the soil· manure, plant debris, composts, and biosolids.

Most changes are small, but significant when considering extreme differences in management practices, it is important to note that often decades of constant management are required to define the ultimate soil organic carbon content that may be reached.

It should be remembered that some soils can potentially hold more carbon than others, i.e. soils with high clay content can store more carbon than sandy soils, regardless of management practices.

Soil carbon losses:

Losses of carbon from soil occur as result of decomposition and conversion of carbon in plant residues and soil organic materials into carbon dioxide. Processes that accelerate decomposition open the losses tap further.

The rate of loss is determined by type of plant and animal matter entering the soil, climate conditions (rainfall, temperature, sunlight) soil clay content and management practices such as frequency and type of cultivation, as well as length and duration of the crop and pasture phases.

Some management practices which reduce carbon inputs and/or increase the decomposition of soil organic matter can also influence carbon losses. These include· fallowing, cultivation, stubble burning or removal and overgrazing.

Soil carbon statement

When looking to store soil carbon within Central West cropping systems other factors, such as weed, disease and moisture management decision must take priority . However, soil carbon is an important part of maintaining the sustainability of central west cropping systems and the adoption of stubble retention has been the first step in reducing the amount of soil carbon lost in a manner that is economically feasible for local growers.

View CWFS 'Factors that influence soil carbon levels' blog, or follow link below·

http·//cwfs.org.au/2015/ 05/19/factors-that-influence- soil-carbon-levels/

Erosion

Impacts of erosion:

Soil formation rates are only a fraction of soil erosion rates. Average soil formation is about 0.14 t/ha per year whereas typical soil losses for cultivated soils range from one to 50 t/ha per year. A one millimetre loss of top soil per year equates to approximately 14 t/ha per year.

The loss of soil results in a loss of nutrients and microbes as well as a reduction in water holding capacity for the crop.

Many of the soil nutrients are classed as immobile and are attached to soil particles. The soil nutrients tend to be concentrated in the topsoil, which means that erosion is removing the immobile nutrients such as phosphorous. This loss of nutrients may also lead to the pollution of offsite environments such as water catchments and river systems.

Methods of erosion control – the three main factors:

1. **Reducing runoff:** Runoff is capable of carrying soil in suspension, which means that by reducing runoff growers are also of reducing runoff include various techniques for increasing soil infiltration rates and soil cover including the retention of stubbles during the fallow period.
2. **Slow wind speed:** Erosion can be reduced by slowing the rate at which the wind travels across the soil surface. This can be achieved by introducing banks, diversions, wind breaks and soil cover.
3. **Keep the soil in place:** By maintaining soil organic matter and soil surface cover the erodibility of the soil is dramatically reduced. This allows the soil to be more resilient against erosive forces such as wind and water (Figure 3).

Ground cover:

Plant and stubble cover can protect the soil by intercepting wind and raindrops, which dissipates the associated energy that reaches the soil surface.

The target level of ground cover is adequate when run-off is minimal and soil erosion does not exceed the rate of soil formation.

Inadequate ground cover can also reduce a soils ability to absorb water during rainfall events, with water running off and into creeks and streams instead.

As the levels of ground cover are reduced, the patches of bare ground start to interconnect. This allows run-off water to flow more freely thus increasing its capacity to erode the soil. If ground cover is present we tend to see the reverse pattern occurring as plants or their residues begin to act as isolated islands slowing the flow rate of water.

Erosion management in stubble retained systems:

It is important that stubble is managed so that there is always an adequate amount for erosion control, and conversely excess stubble is managed to avoid blockages in machinery and negatively impact on crop establishment.

Wheel tracks of machinery may start to concentrate water within the paddock low points. Further research is still needed within the central west area to determine the best sowing direction in relation to slopes.

When sowing, the soil should be disturbed as little as possible, especially on steeper slopes, as seedlings provide little or no reduction to soil erosion immediately following planting.

Frequent cultivation and stubble burning should be avoided wherever possible, as both practices will leave the soil bare during the summer storm period and the crucial time of crop establishment. As a compromise a late burn is a better management option compared with no stubble retention during the summer fallow period.

References

- https://www.researchgate.net/ publication/ 29452631_Wind_Erosion_Monitoring_and_Modeling_Techniques_in_Australia
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- The significance of carbon–enriched dust for global carbon accounting· Grant McTainsh , Griffith University 2012
- Managing Australia's Soils· A policy discussion paper· CSIRO 2012
- Wind Erosion Assessment for National Landcare Program· Authors· John Leys a , Adrian Chappell b , Jodie Mewett c and Michele Barson - NSW Office of Environment and Heritage, Gunnedah NSW 2380 Injekta Field Systems, Cavan, South Australia 5094 Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra ACT 2612 Sustainable Agriculture, Fisheries and Forestry Division, Department of Agriculture and Water Resources, Canberra ACT 2602

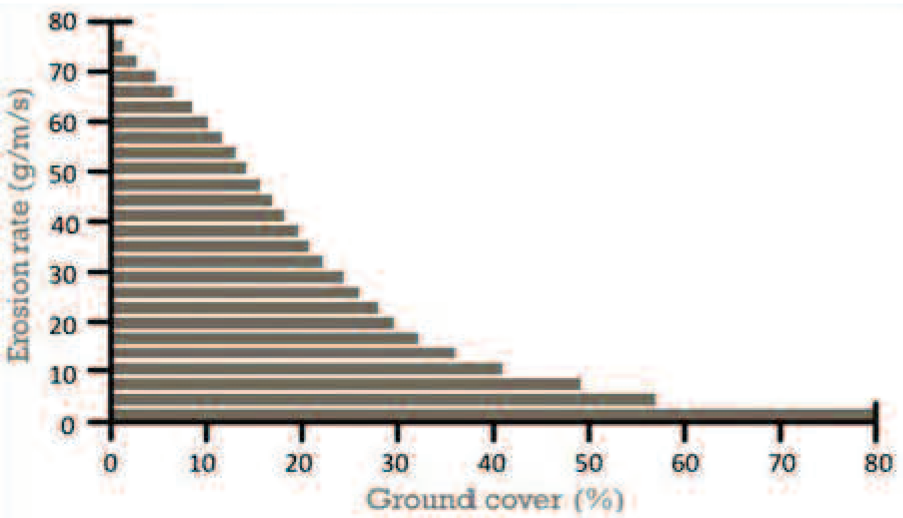

Figure 3. Effect of prostrate cover in reducing wind erosion (Leys, Butler and McDonough, 1994)

Disclaimer

This guideline has been developed by Central West Farming Systems Inc. (CWFS) as part of the Maintaining Profitable Farming Systems with Retained Stubble initiative, funded by the Grains Research and Development Corporation (GRDC). The initiative involves farming systems groups in Victoria, South Australia, southern and central New South Wales and Tasmania collaborating to validate current research at a local level and address issues for growers that impact the profitability of cropping systems with stubble; including pests, diseases, weeds, nutrition and the physical aspects of sowing and establishing crops in heavy residues.

During 2012 discussions with local producers resulted in CWFS identifying 13 subjects that impact on the management decisions for producers in Central West NSW.

Since then CWFS has undertaken a range of research, development and extension (RD&E) activities focusing on these subjects. These publications are an attempt to capture those activities and provide regionally specific guidelines for producers aiming to retain stubble in Central West NSW.

A primary part of this work has been to correlate existing resources and research from several organisations and CWFS thanks these respective organisations for their work. CWFS and the GRDC also thank the experts who technically reviewed these guidelines.